逆反射可见光通信与定位

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大纲摘要

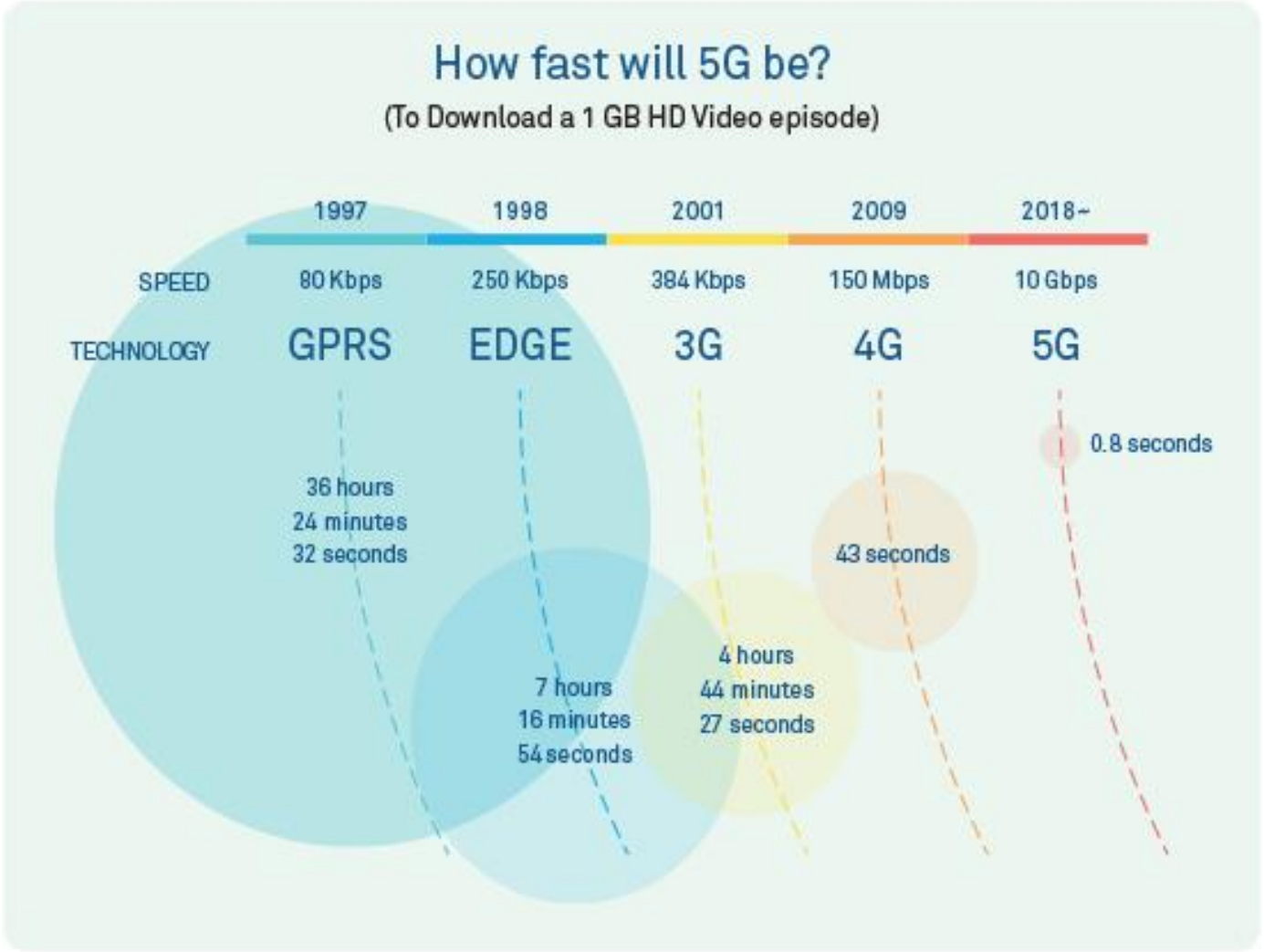
- 可见光通信符合频谱探索中的大趋势
- 以特定光源为基础的可见光通信适用于下行链路
- **逆反射可见光通信的优势与局限**
- **基于角立方逆反射的室内定位**
- 探讨逆反射可见光的应用前景

无线通信技术的发展历程

Basic Phone Call

Short Message Service

Multimedia Message Service



Massive Connections

Ultra-low Latency

Ultra-high Speed

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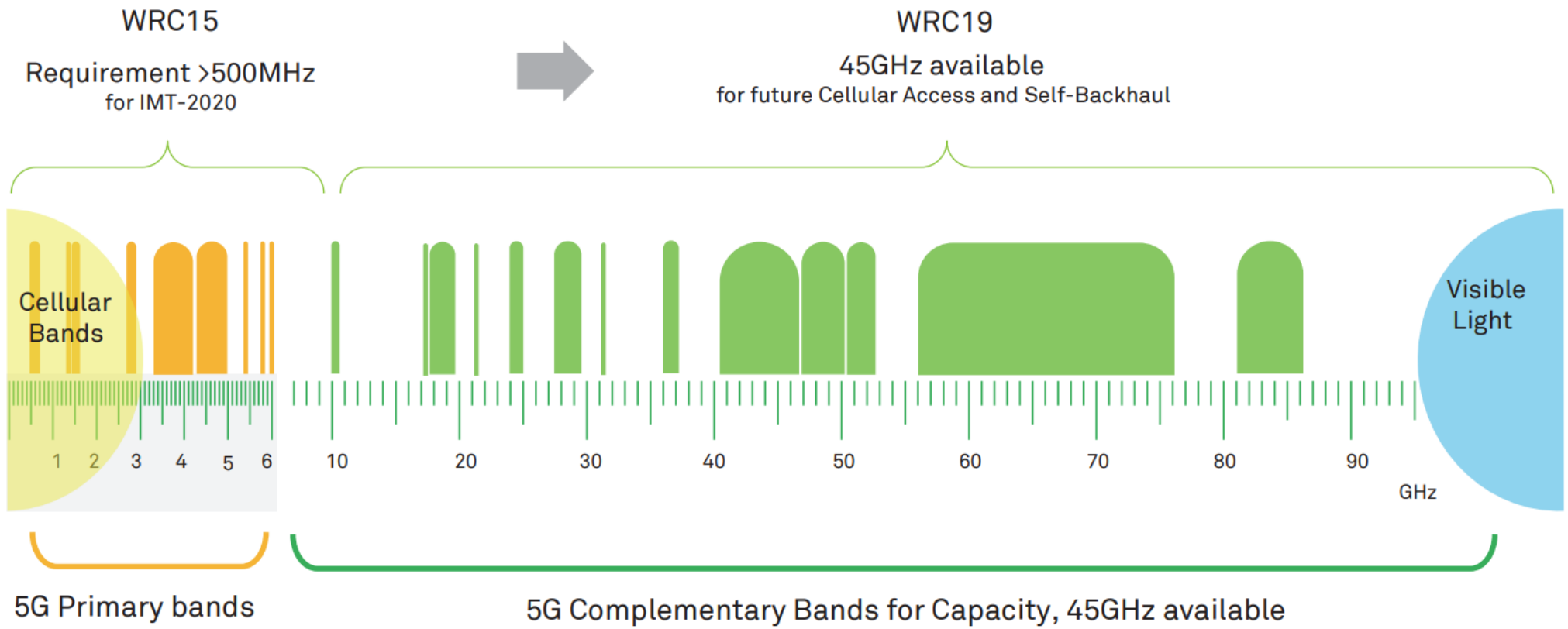
5G通信在频谱使用上的拓展



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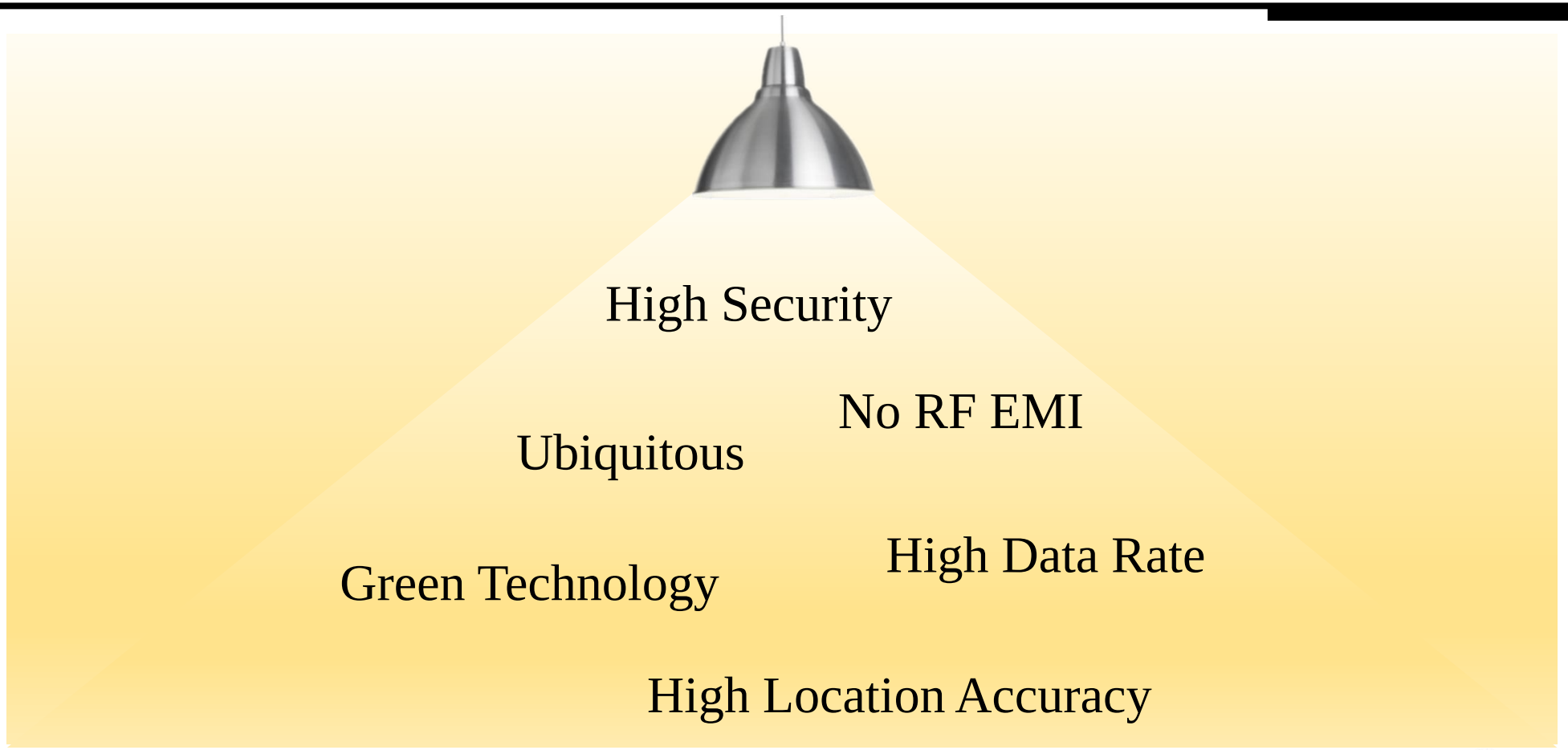
可见光通信能否有一席之地?



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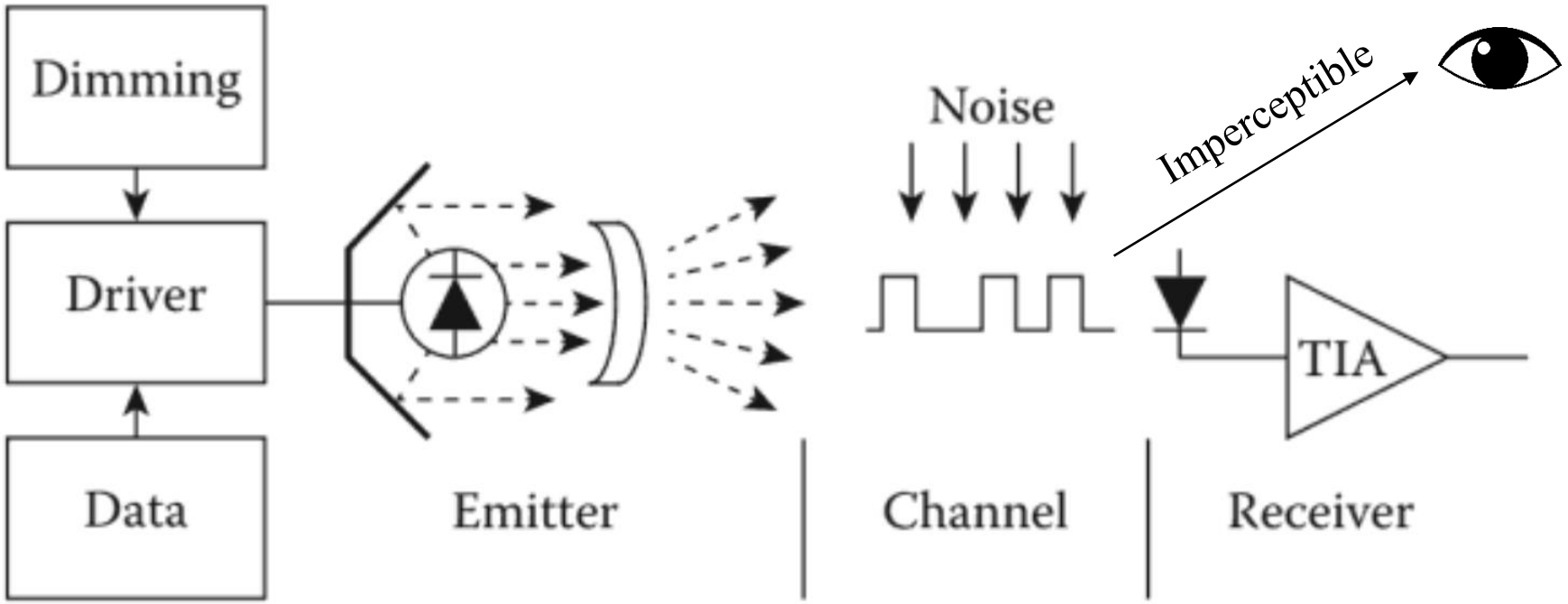
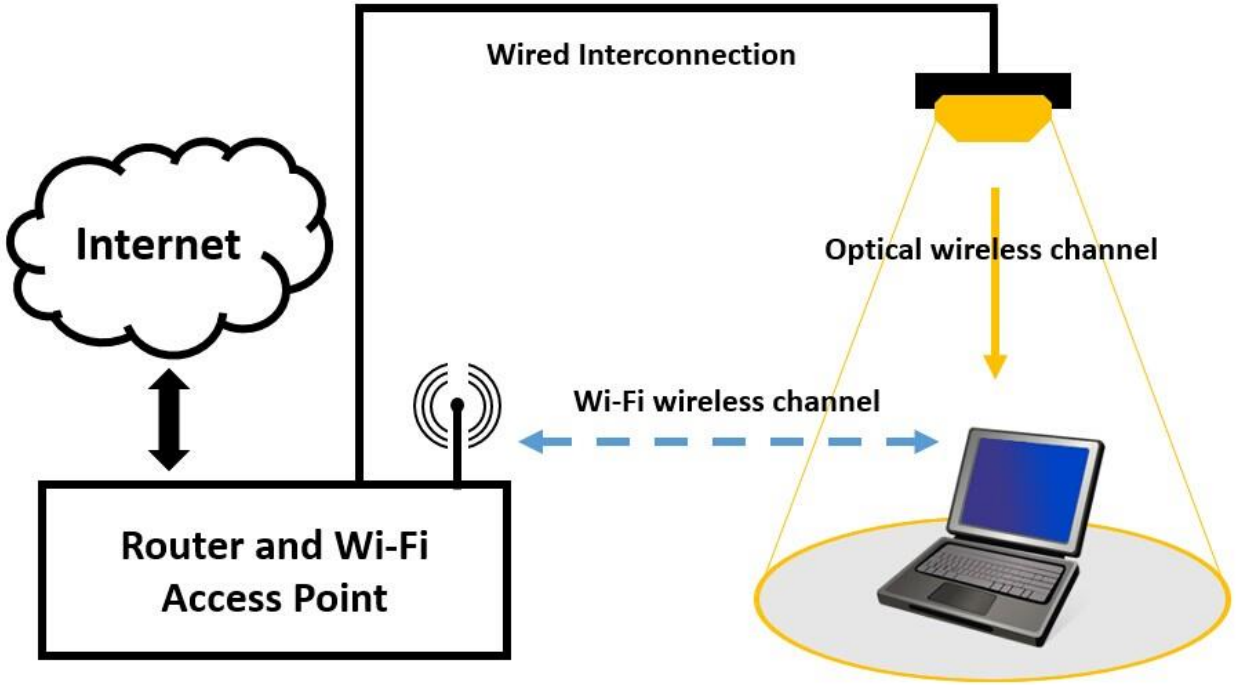
传统意义上的可见光通信系统



可见光通信连入因特网 – 上行链路?

- Uplink of VLC is a challenge.
- Incorporate RF uplink could be a solution.



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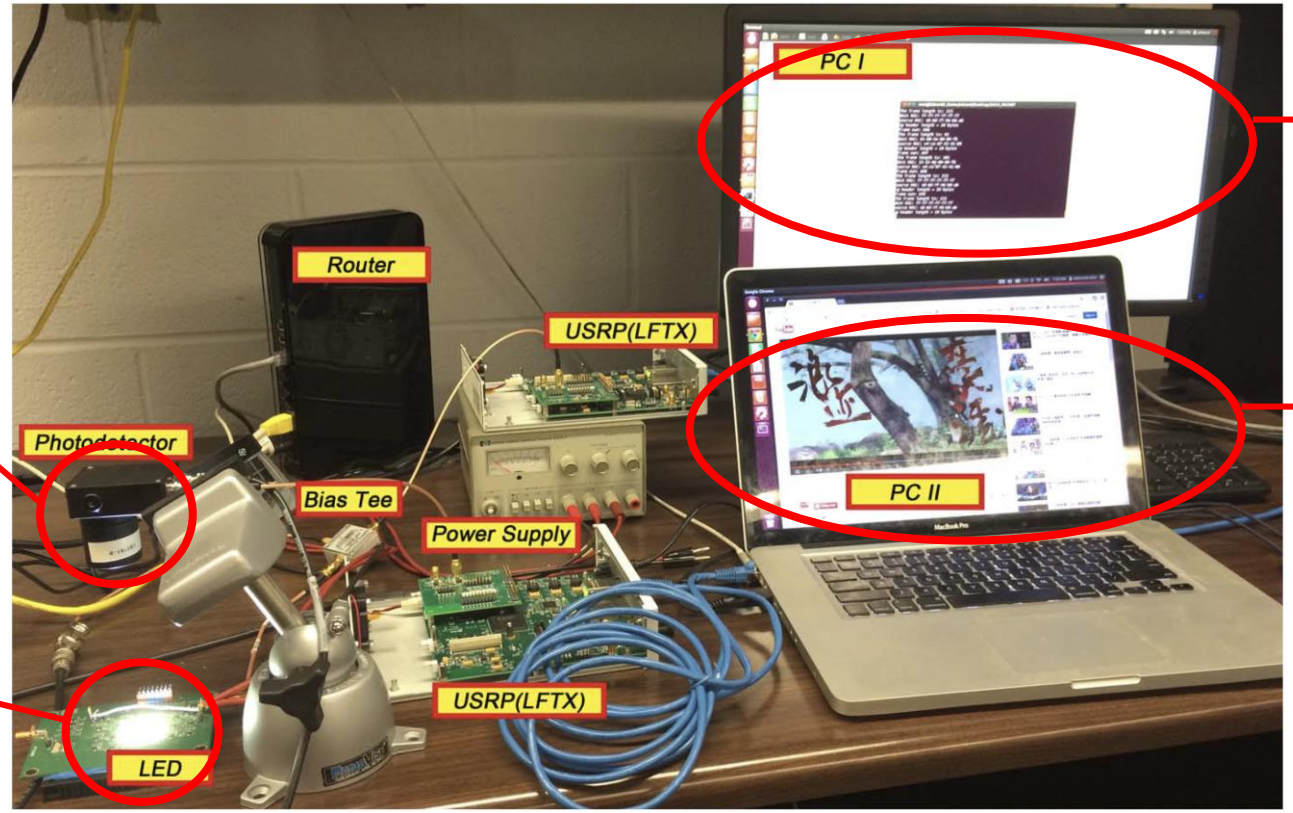
可见光通信连入因特网 – 实验平台

- In the following video, we show a testbed using visible light communication (VLC) to connect to the Internet.



The client that is connected to the Internet

The receiver

The controller for software-defined VLC

The light source

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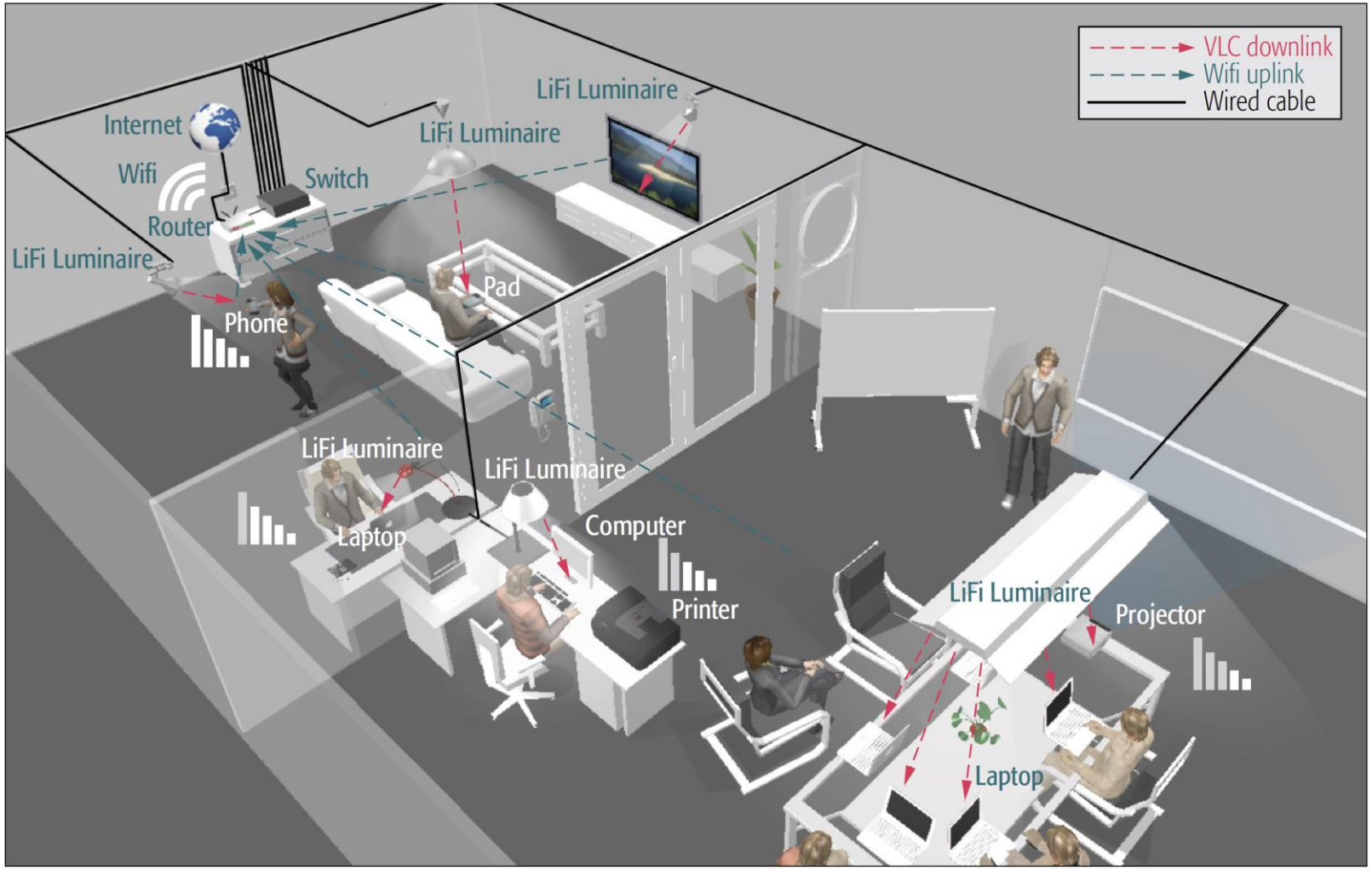
VLC Connect to the Internet

室内可见光+WiFi异构无线网络



The coexistence of LiFi and WiFi leverage ubiquitous LiFi luminaire to alleviate the wireless radio channel congestion and provide better quality of experience to the end users.

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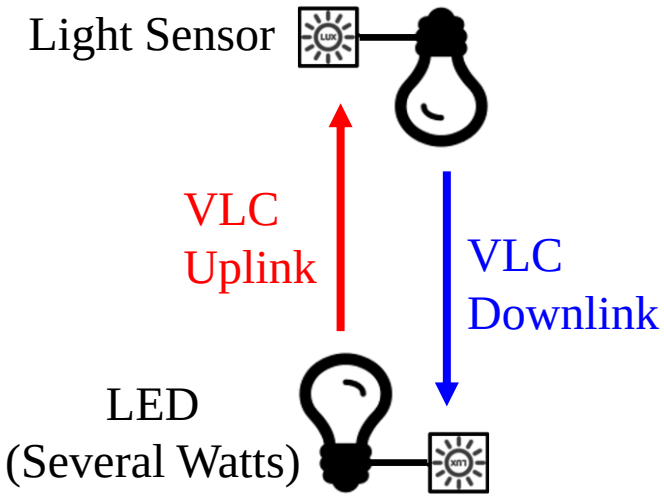
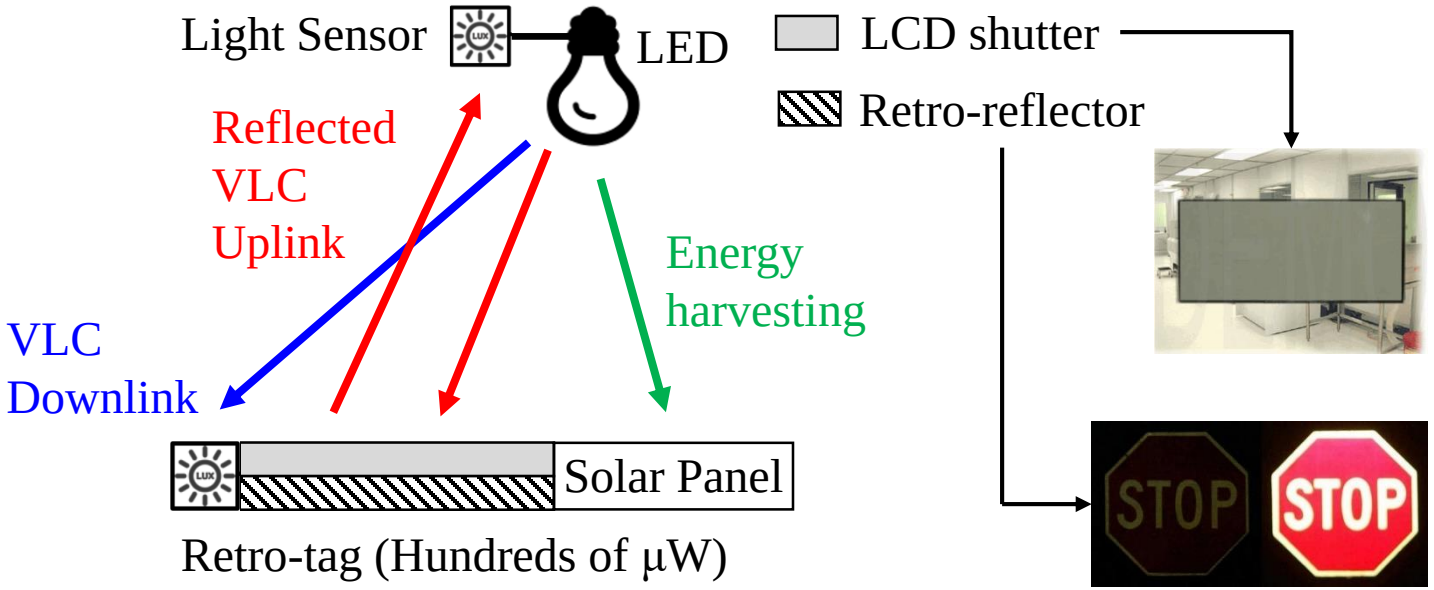
逆反射可见光通信的优势

Conventional Symmetric VLC



- High power
- Miss uplink alignment
- Potential uplink glaring
- Bulky size

Ultra-low-power Asymmetric Retro-VLC



- Ultra-low-power uplink transmission
- Uplink alignment ensured by retro-reflectivity
- No diffused uplink glaring light
- Small size and light weight

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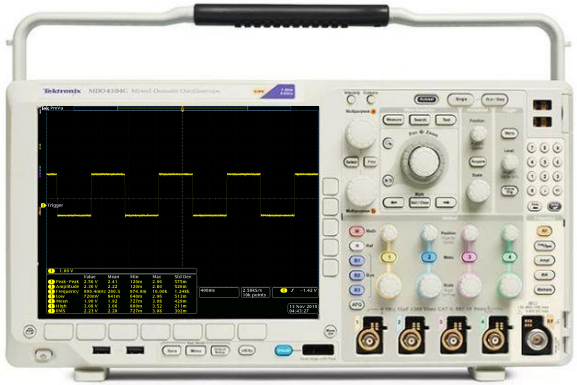
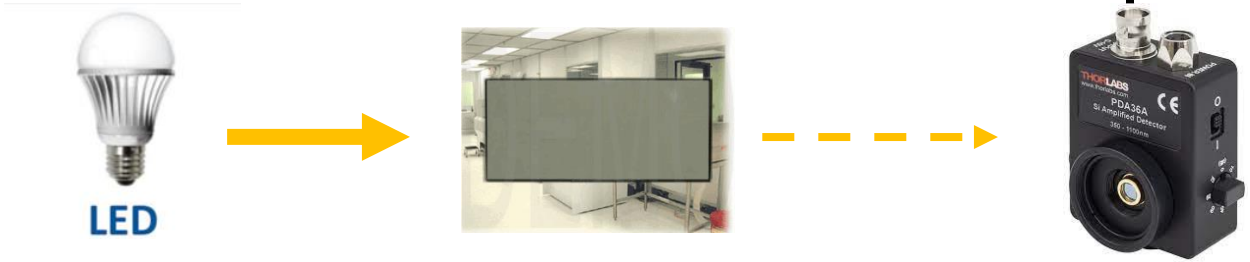
逆反射可见光通信的局限 – 带宽

- Twisted Nematic shutter:
  - Low voltage (~ 3.3 V)
  - Low frequency (~ 200 Hz)
- Pi-cell shutter:
  - High voltage (> 10 V)
  - High frequency (up to 5 kHz)

Let's do some experiments:





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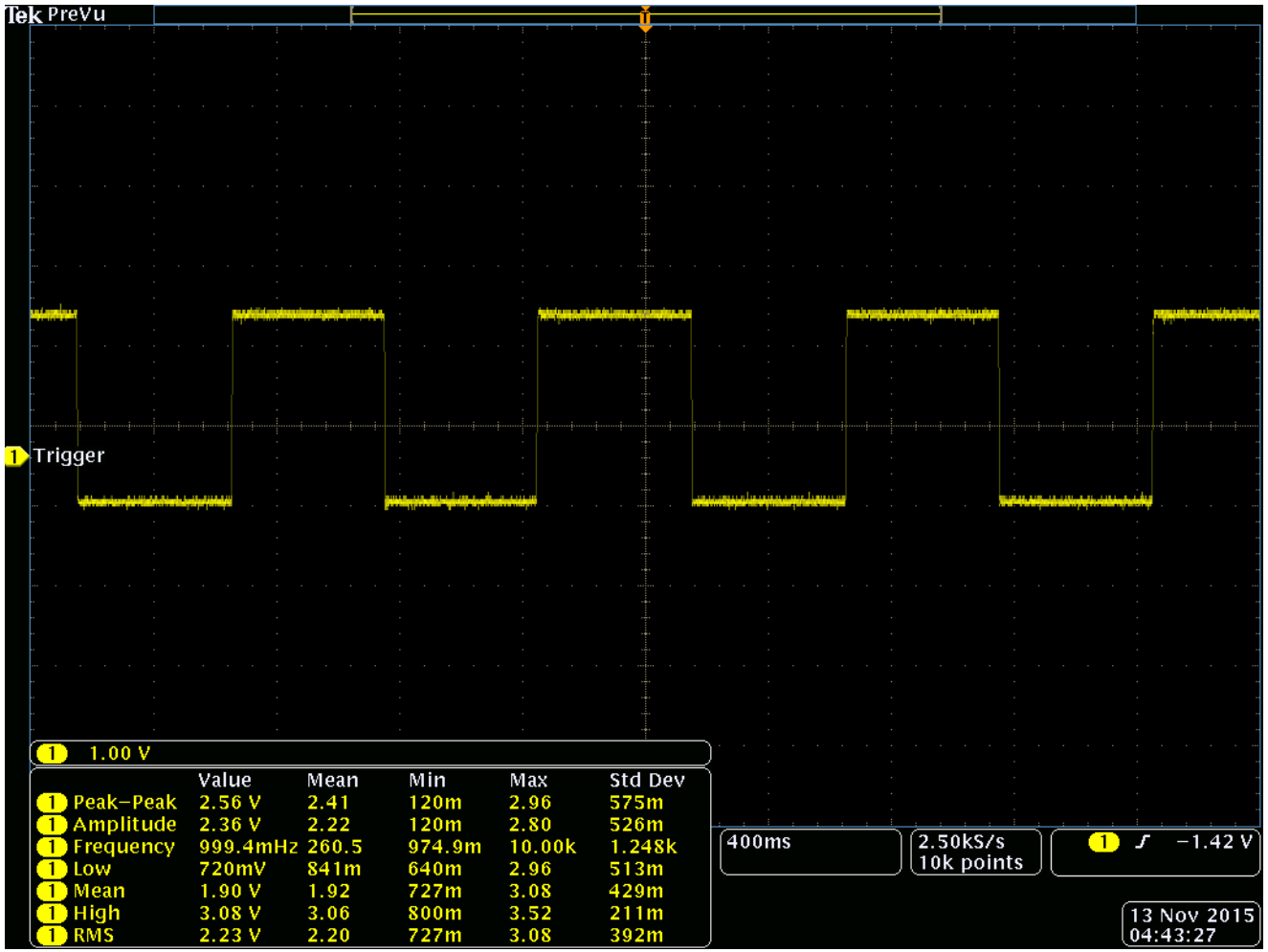
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

2 Hz

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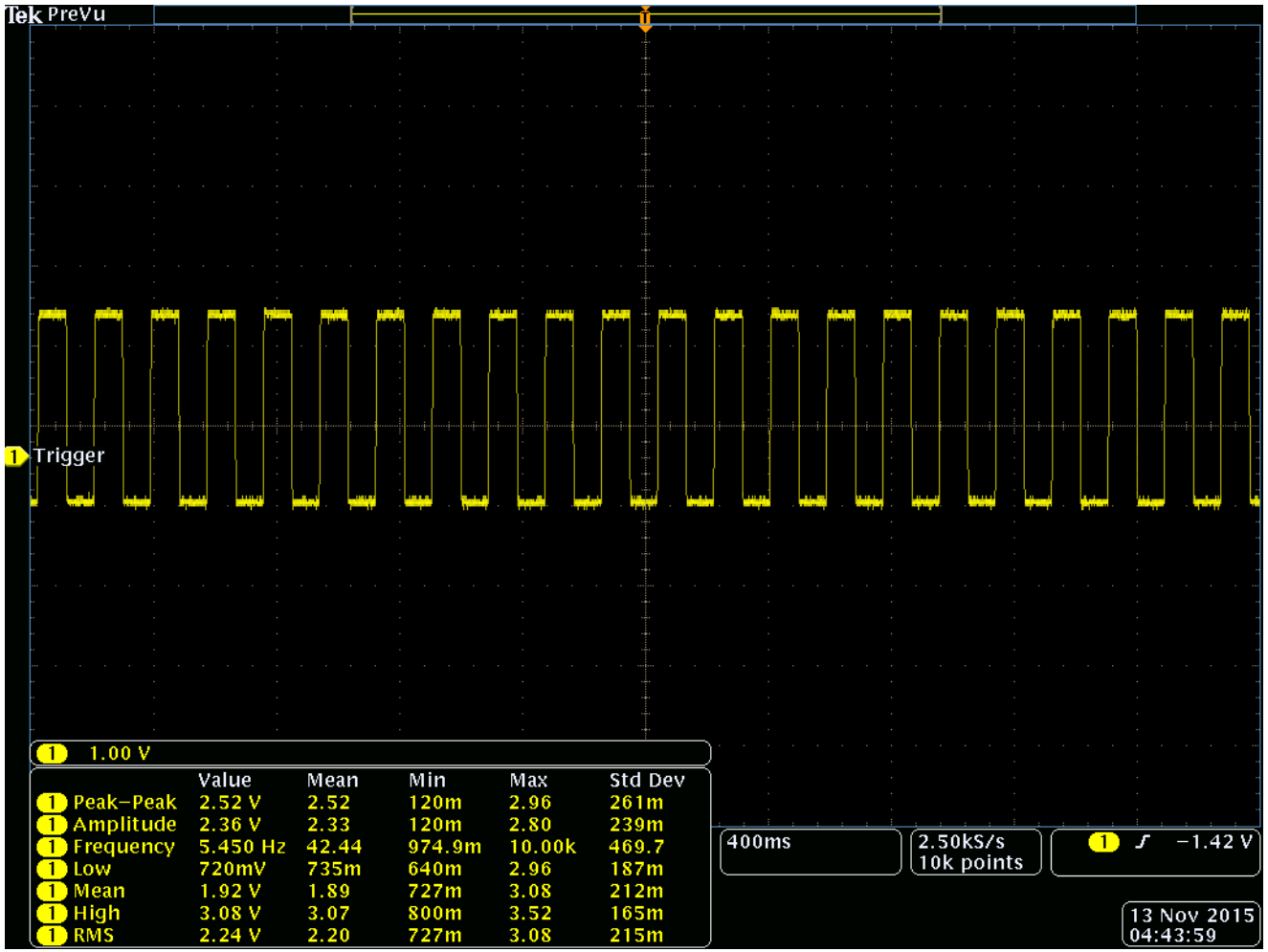
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

10 Hz

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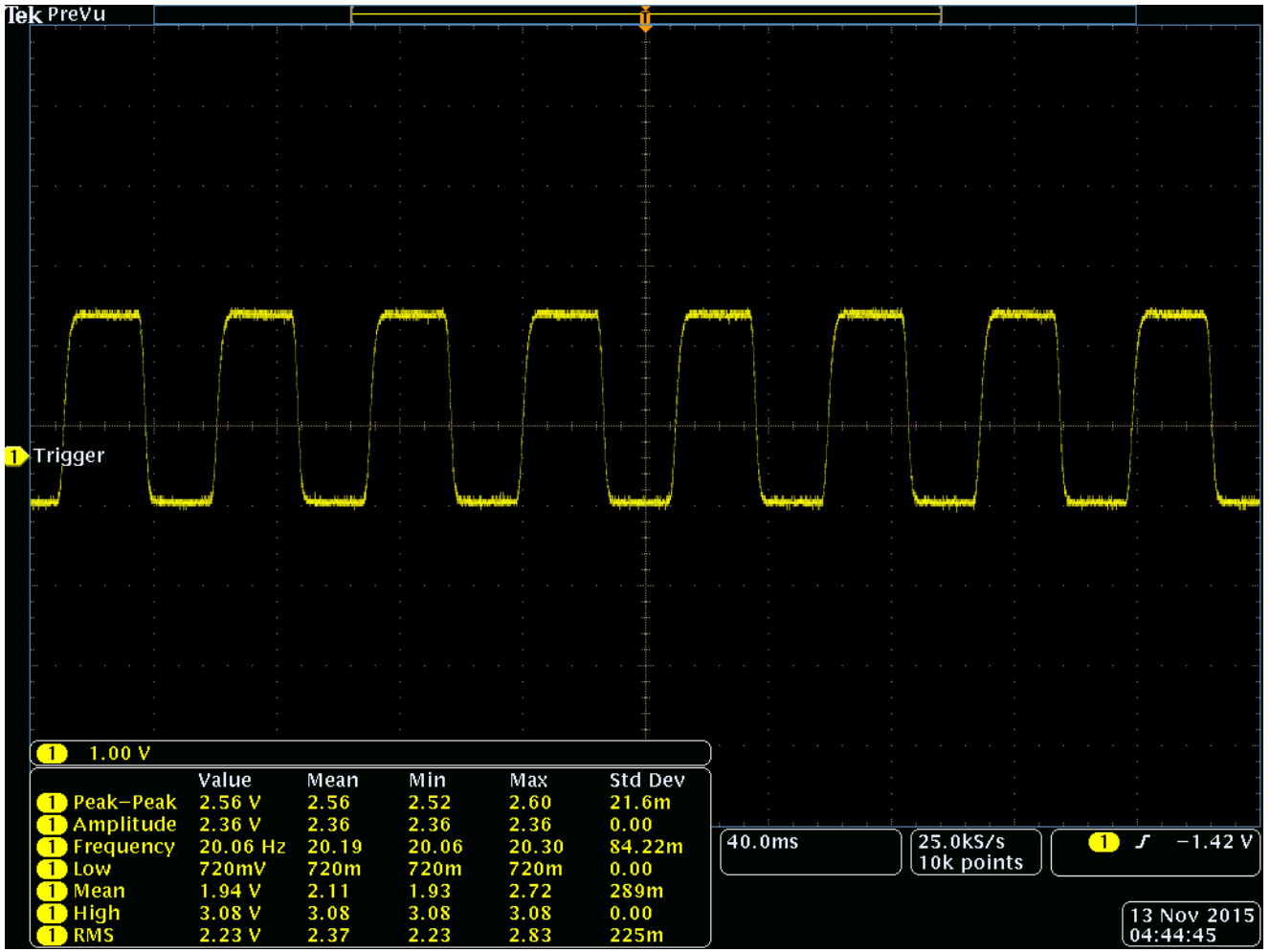
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

40 Hz

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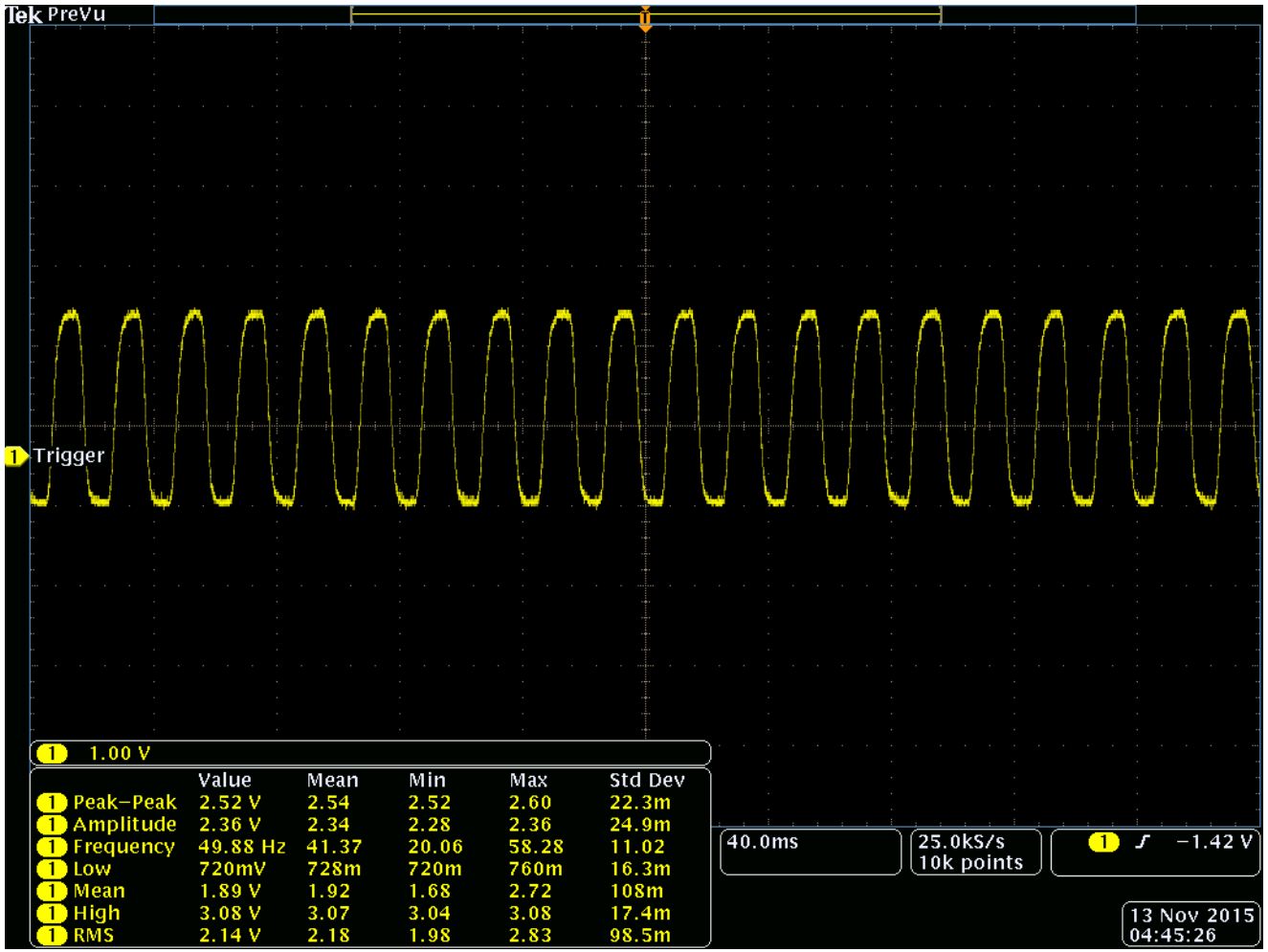
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

100 Hz

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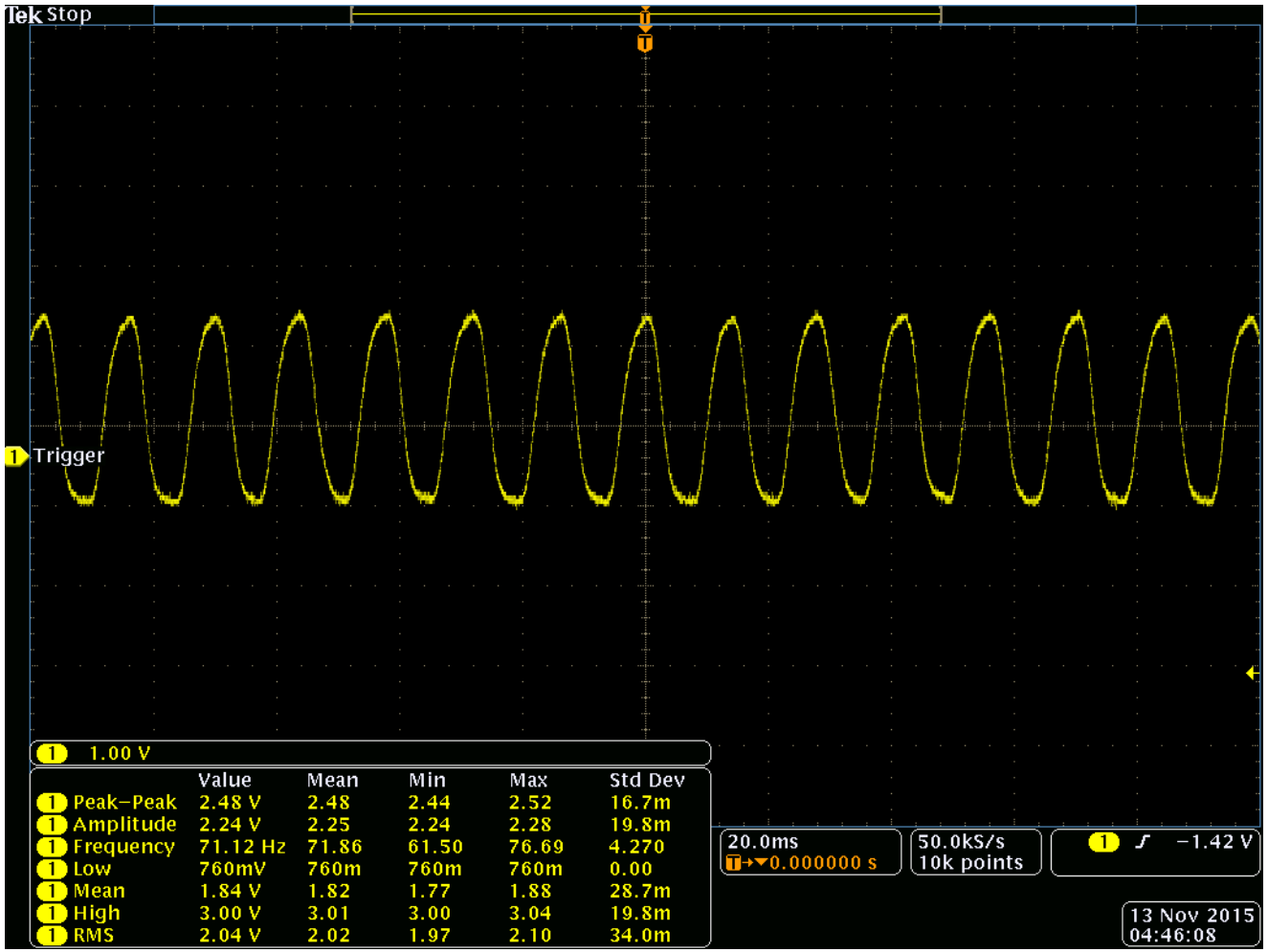
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

140 Hz

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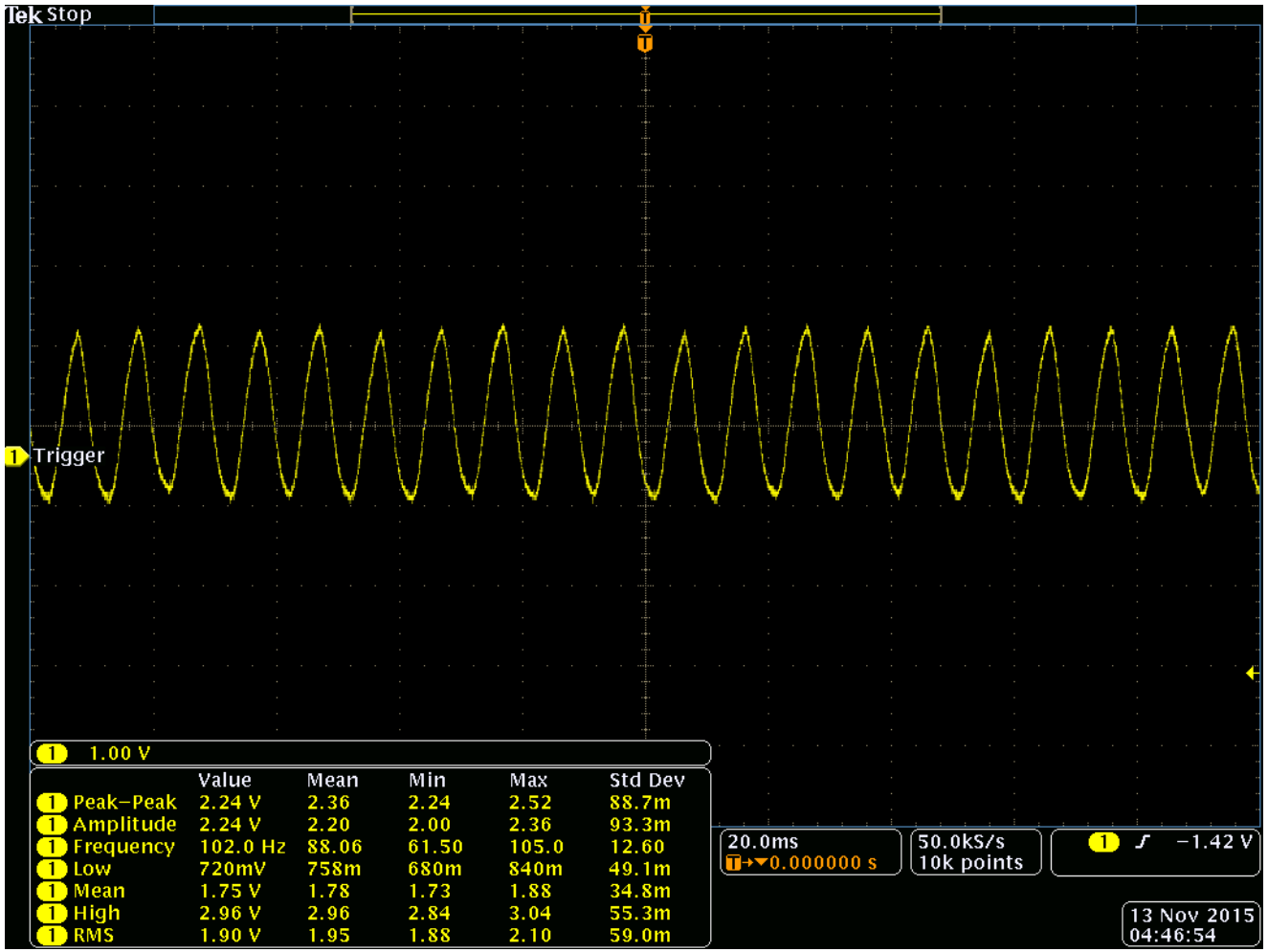
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

200 Hz

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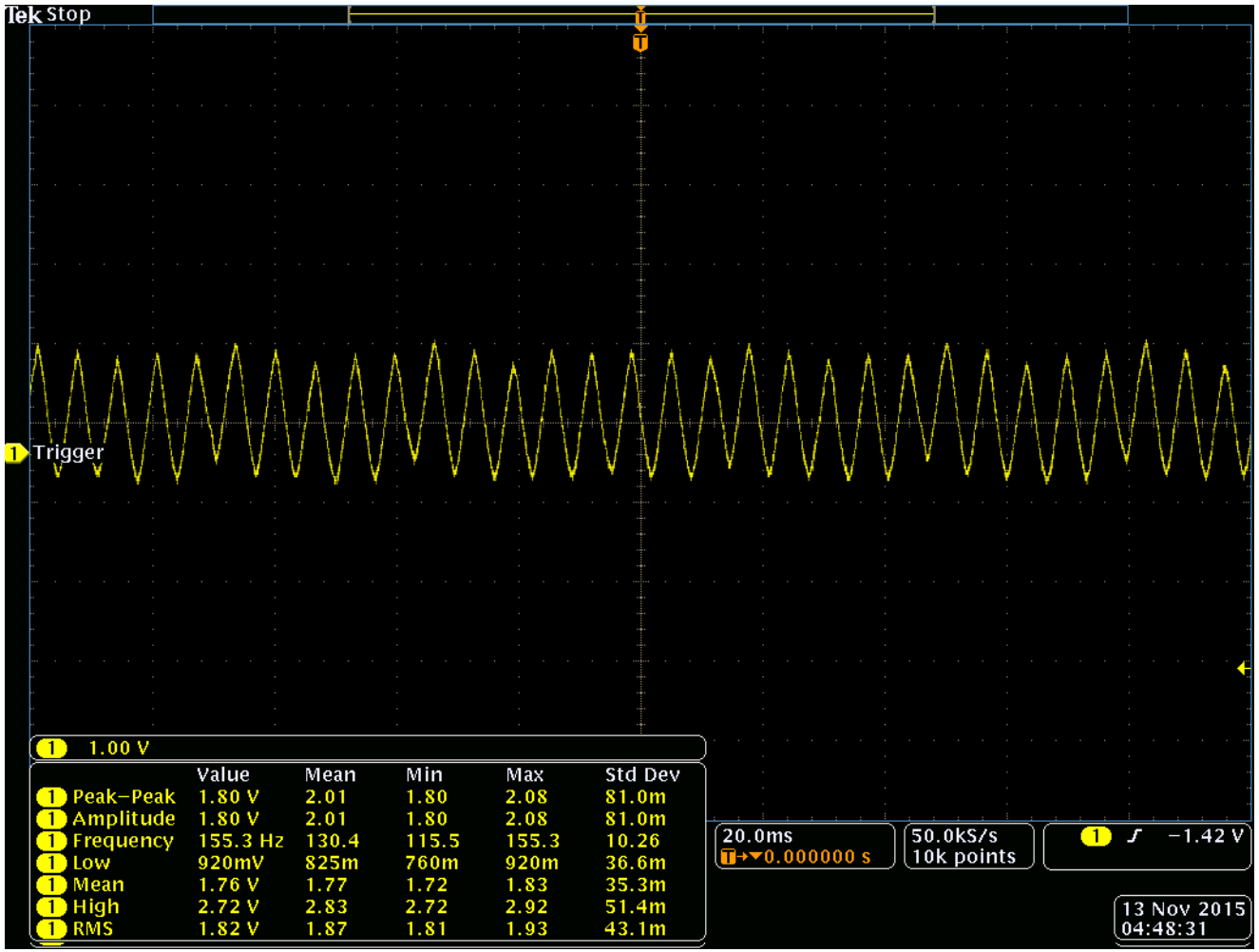
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

300 Hz

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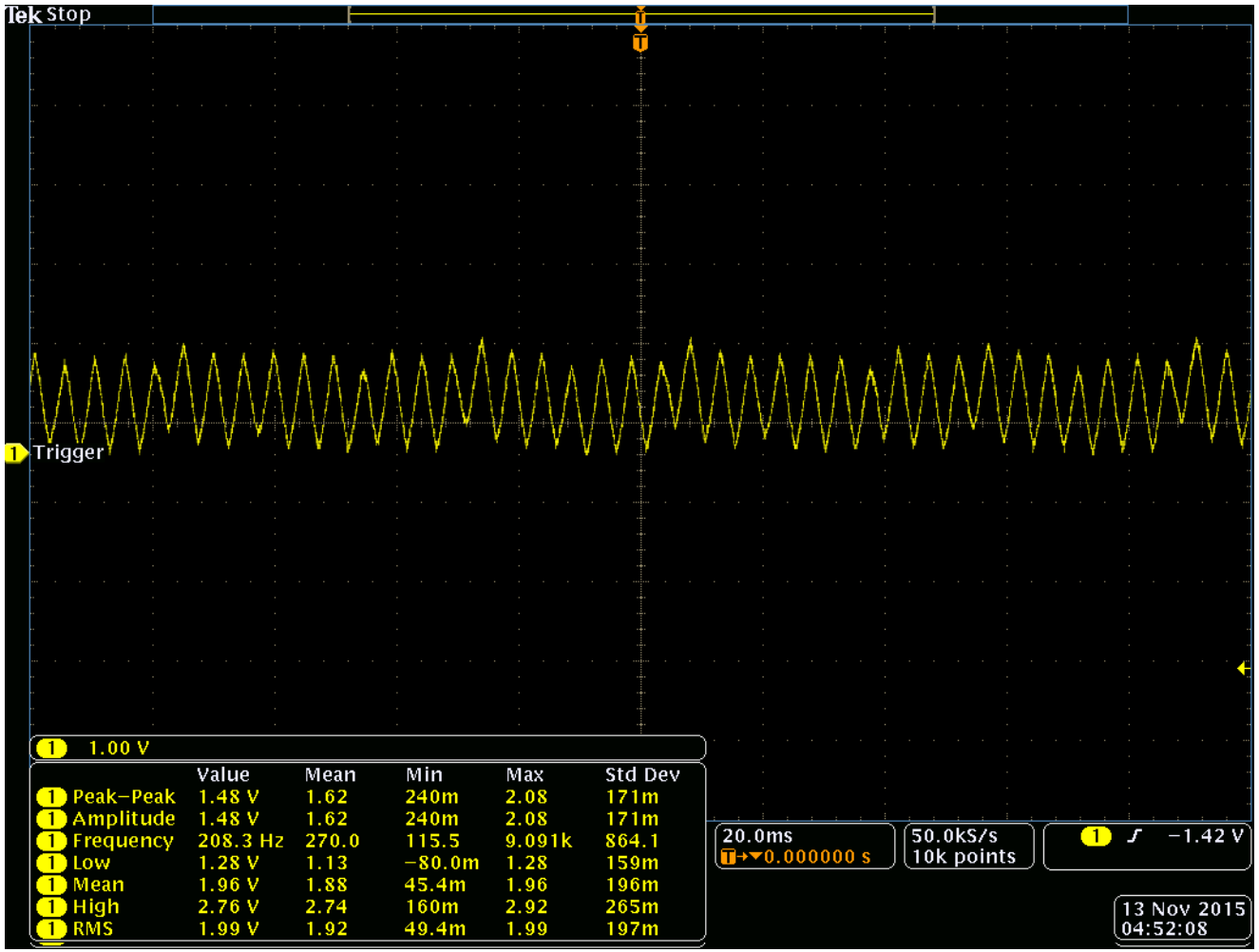
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

400 Hz

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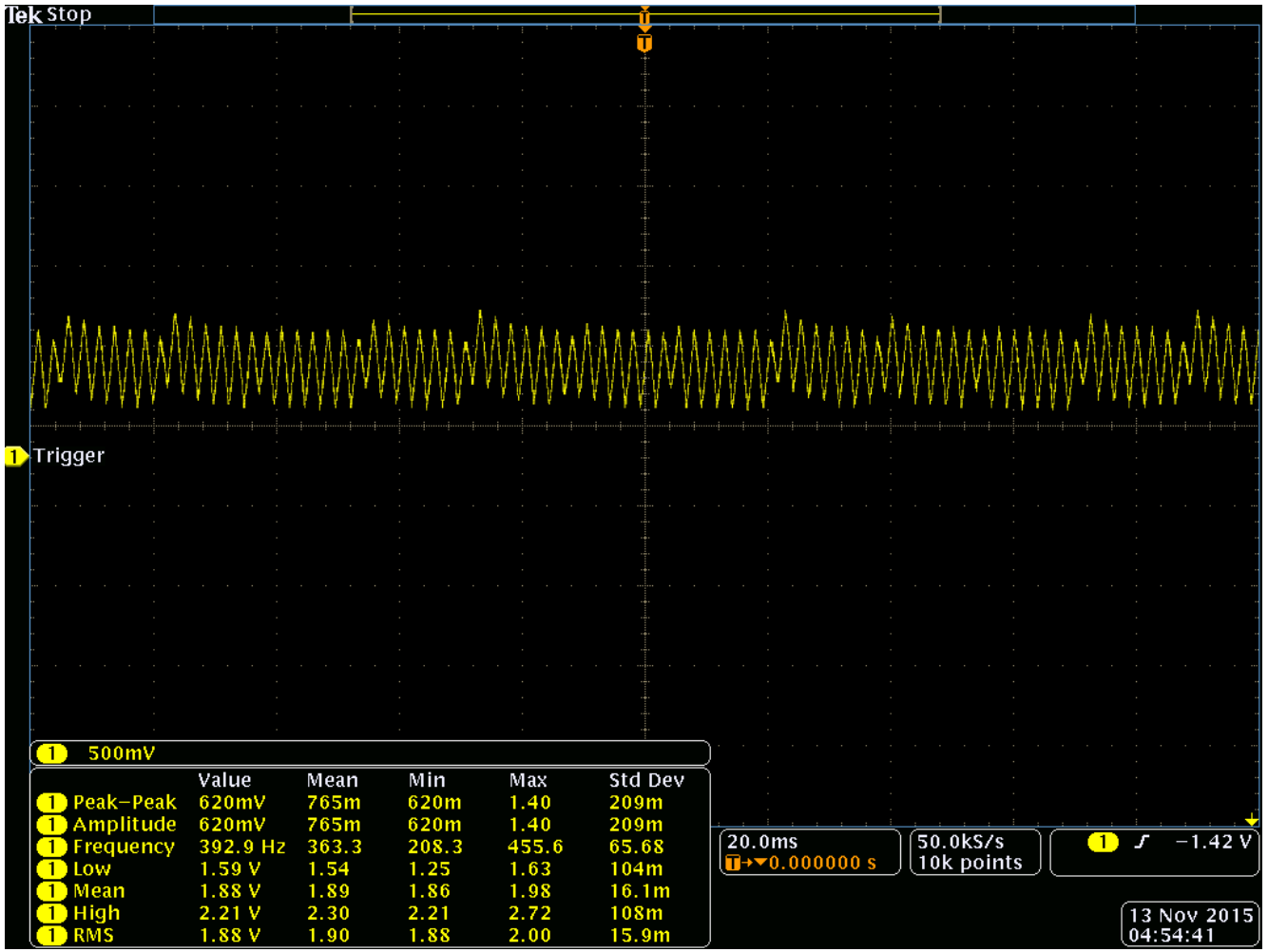
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

800 Hz

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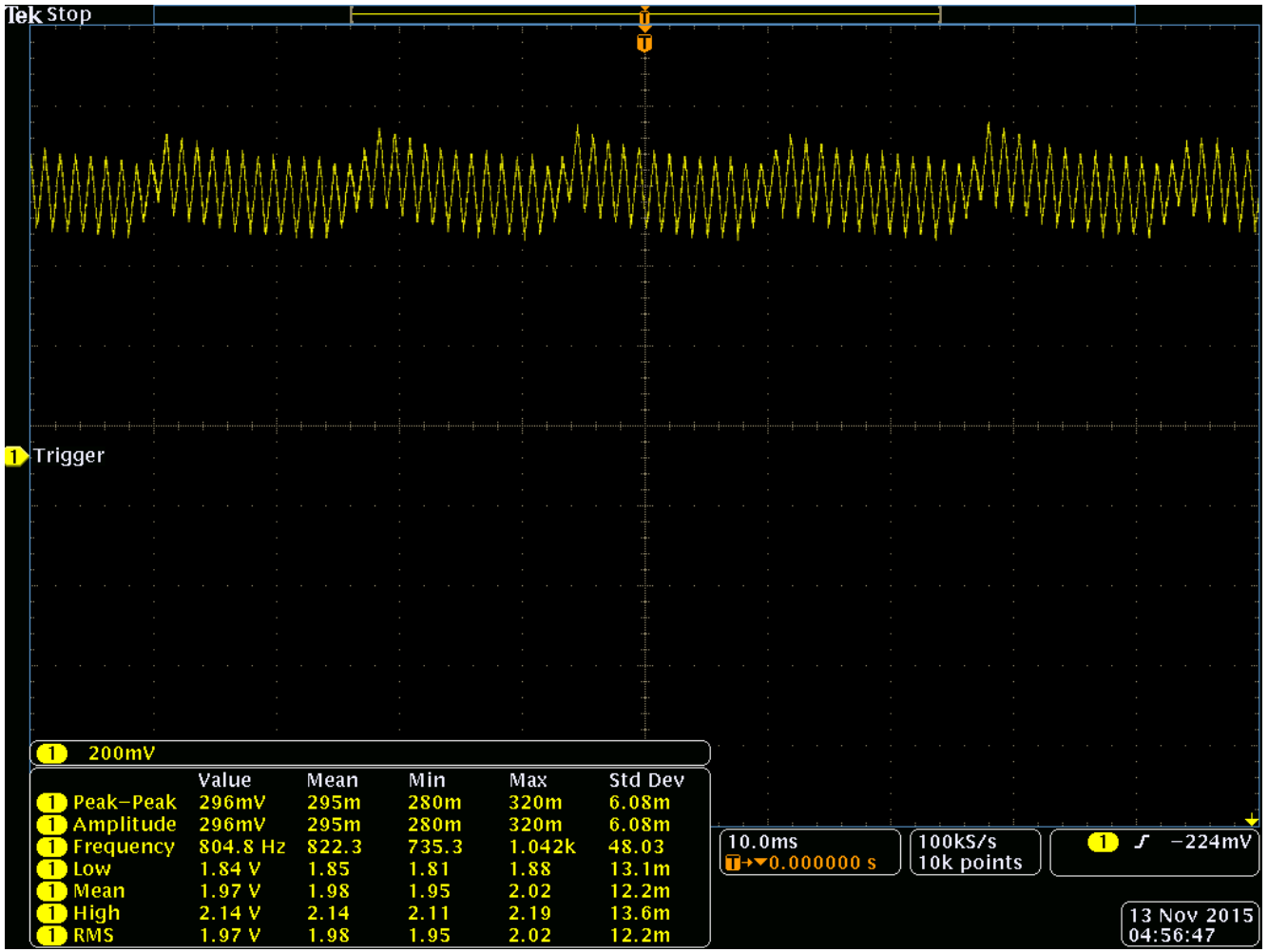
逆反射可见光通信的局限 – 带宽测试



Modulation Frequency

1600 Hz

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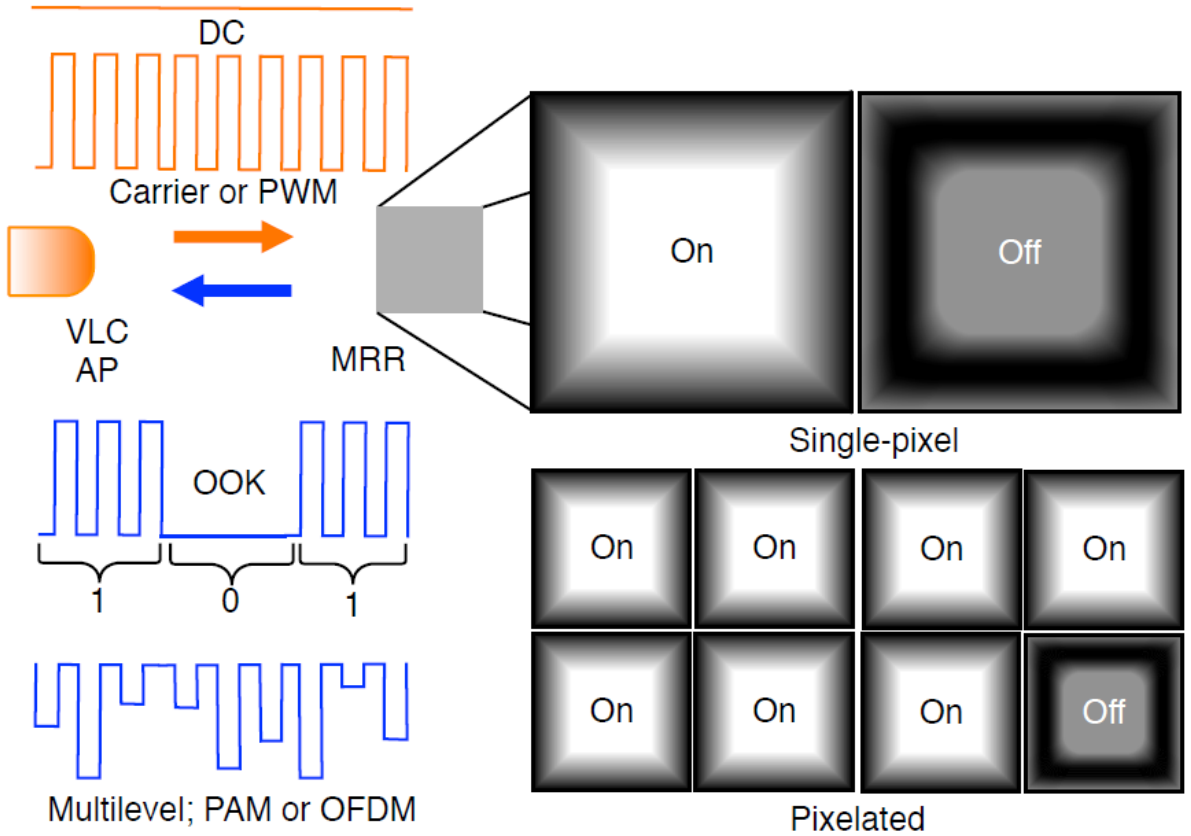
逆反射可见光通信 - 像素化设计

- Instead of using one shutter, multiple smaller shutters form the pixelated Retro-VLC tag.
- Smaller LCD shutters has faster switching speed.
- Multi-level optical signals are enabled.
- PAM, OFDM modulation schemes are possible.



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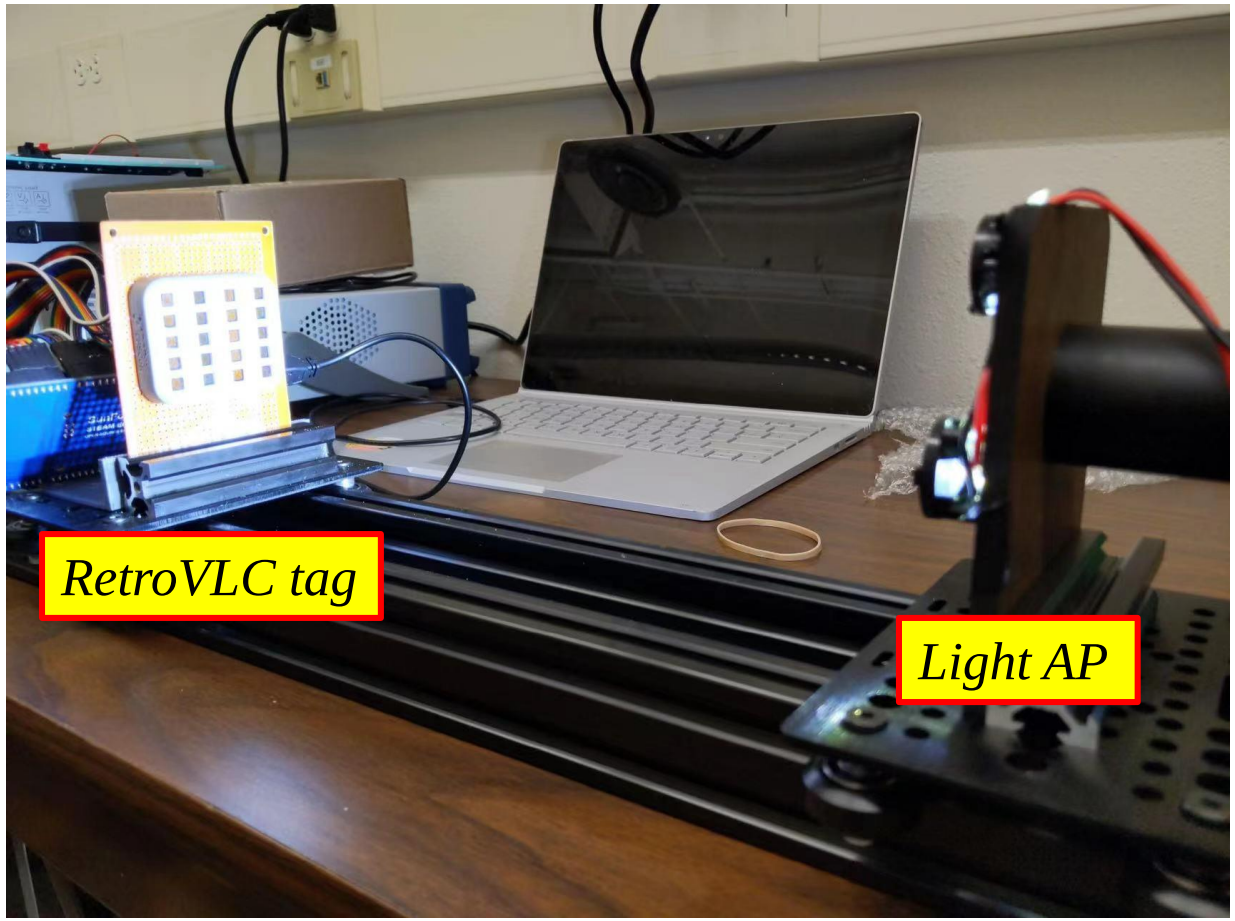
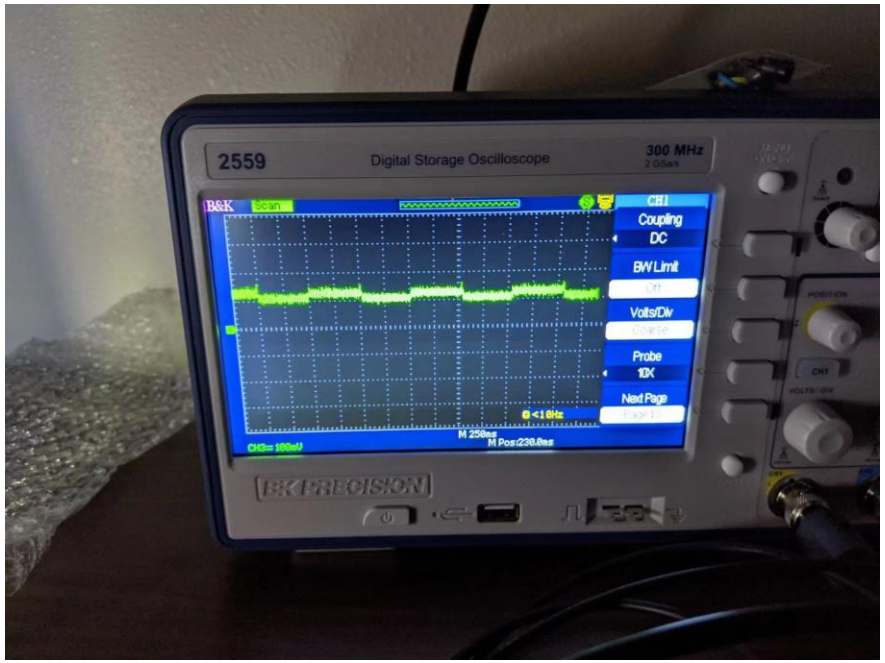
逆反射可见光通信 – 像素化实验平台





A square wave signal from RetroVLC tag

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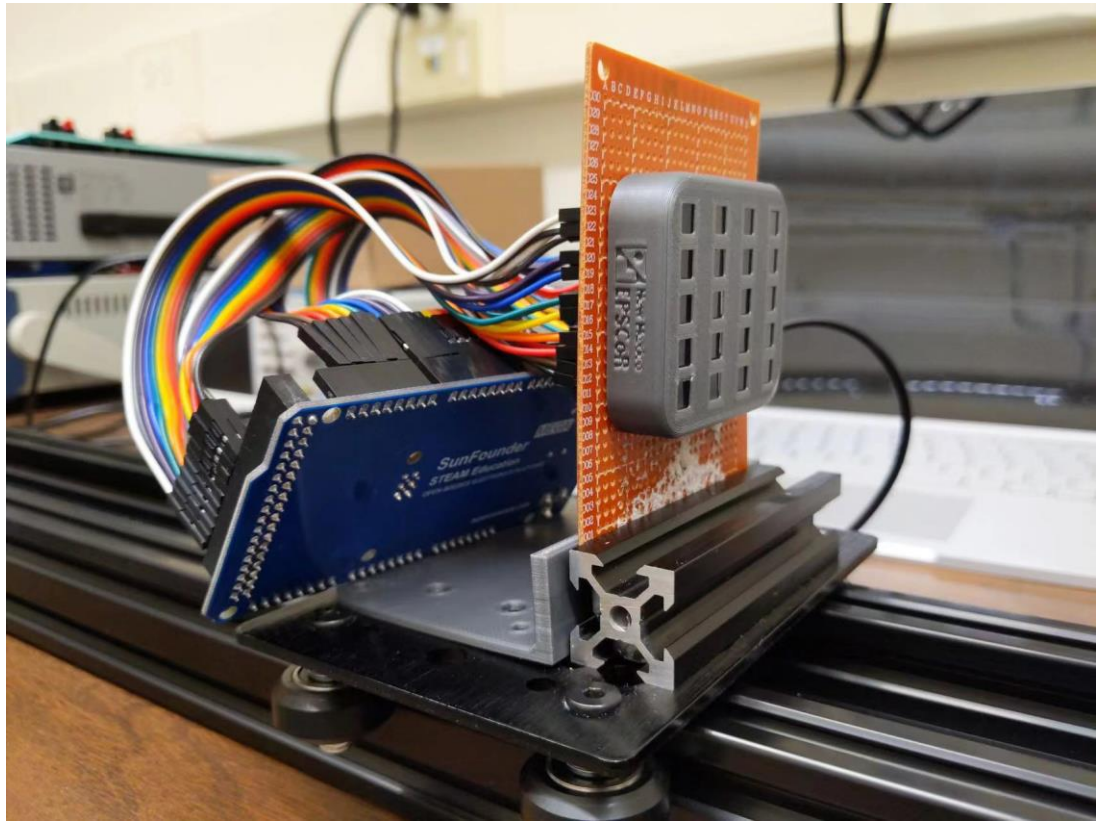
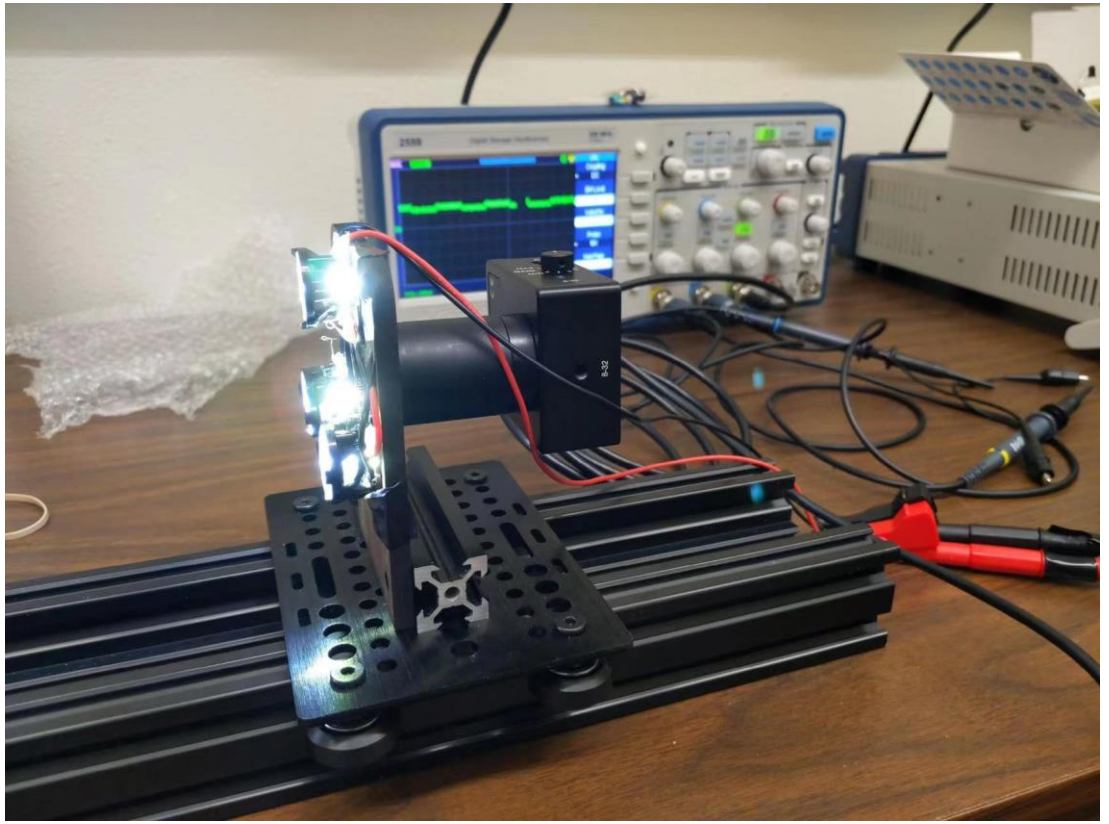
逆反射可见光通信 – 像素化实验平台



MCU controlled pixelated RetroVLC



Light Source + Avalanche PD

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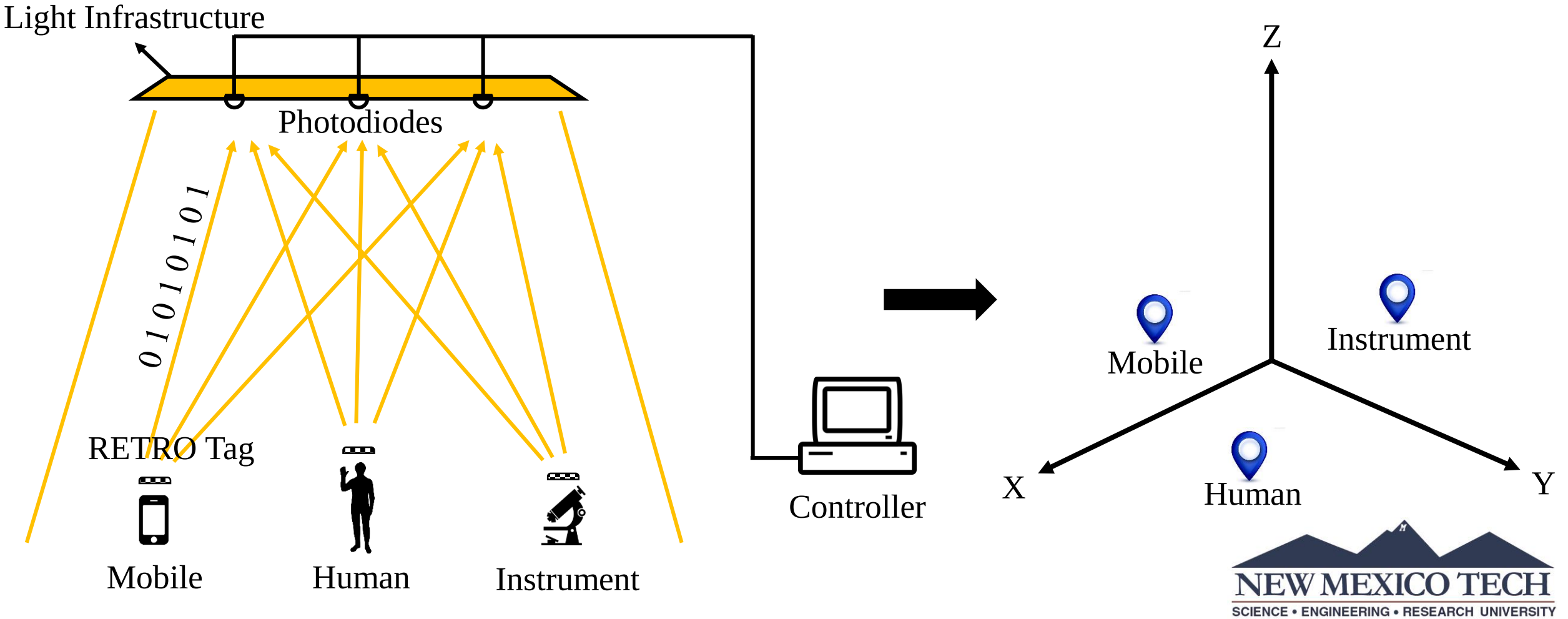
基于角立方逆反射的室内3D定位系统



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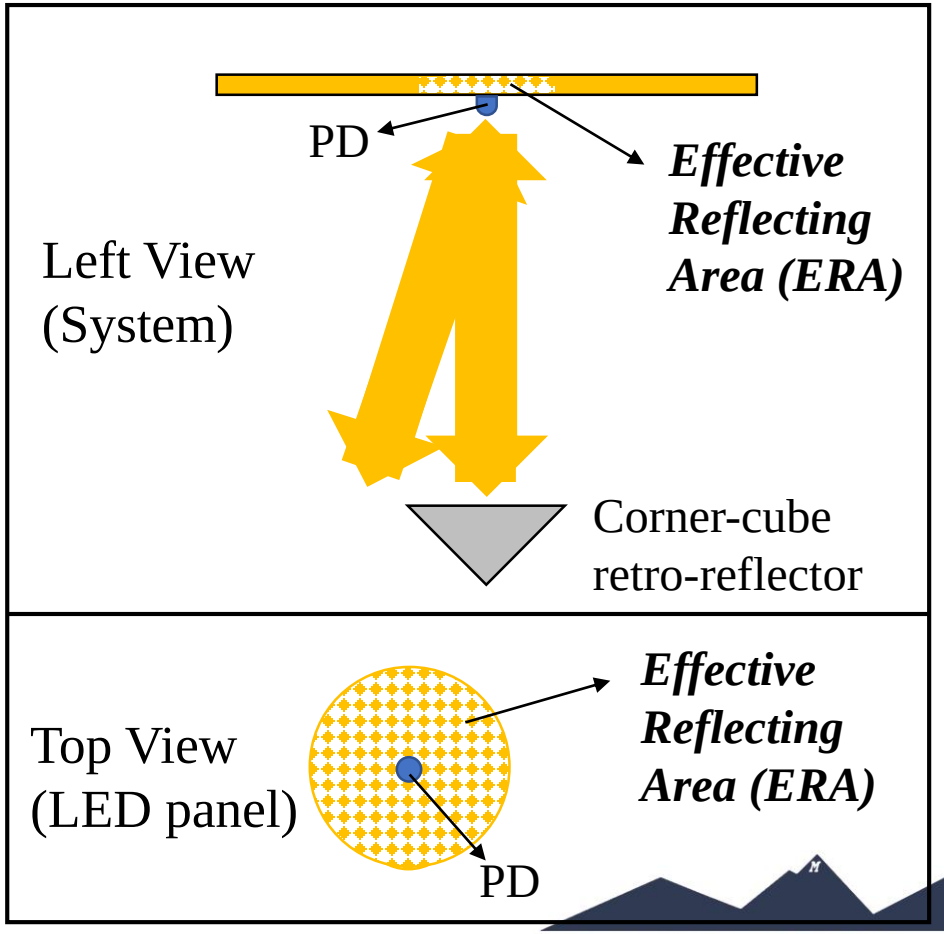
角立方逆反射可见光定位 – 设计难点

- **RSSI and Trilateration based Localization**
  - Key Feature: When retro-reflector changes its location and orientation, the received optical power on each PD will change.

*Correlate the **effective reflecting area** with the **location** of retroreflector?*



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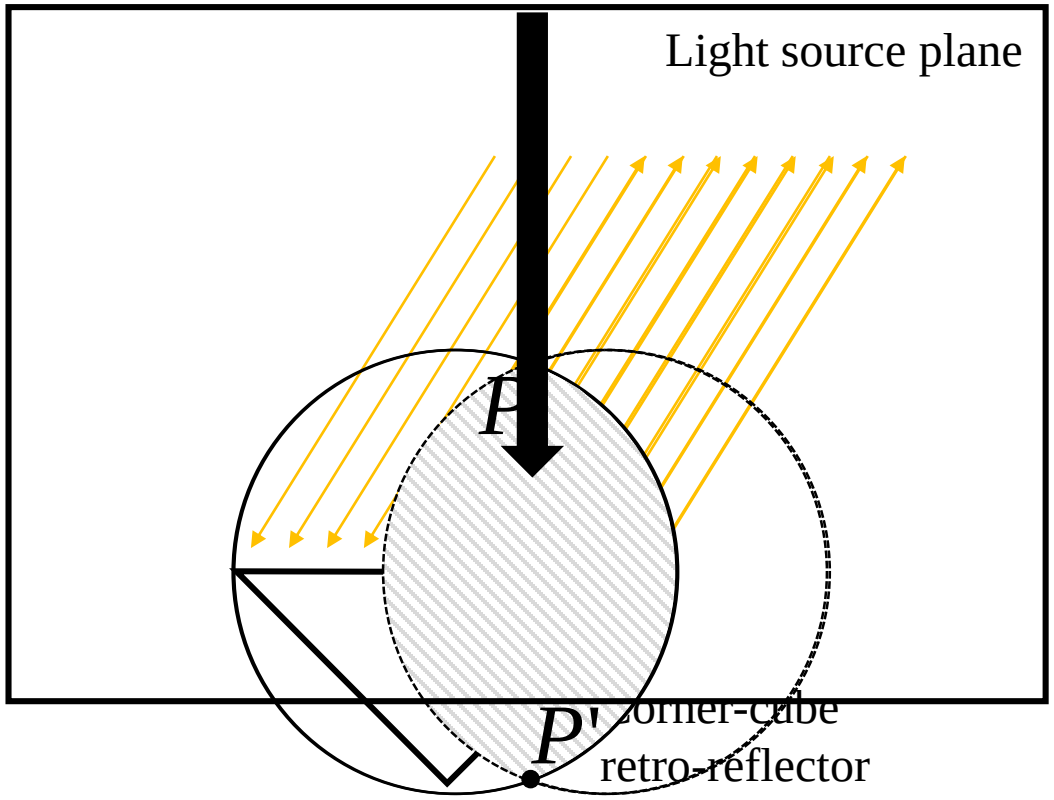
角立方逆反射可见光定位 – 设计思路

❑ **Derive Effective Reflecting Area (ERA)**

Light rays hit into this region will be retro-reflected.



Step 1: Map the overlapped region to the light source plane.
$P \rightarrow$ photodiode
$P' \rightarrow$ symmetric point

Step 2: Rotate the overlap region around P.

Step 3: Trajectory of P' bounds ERA.

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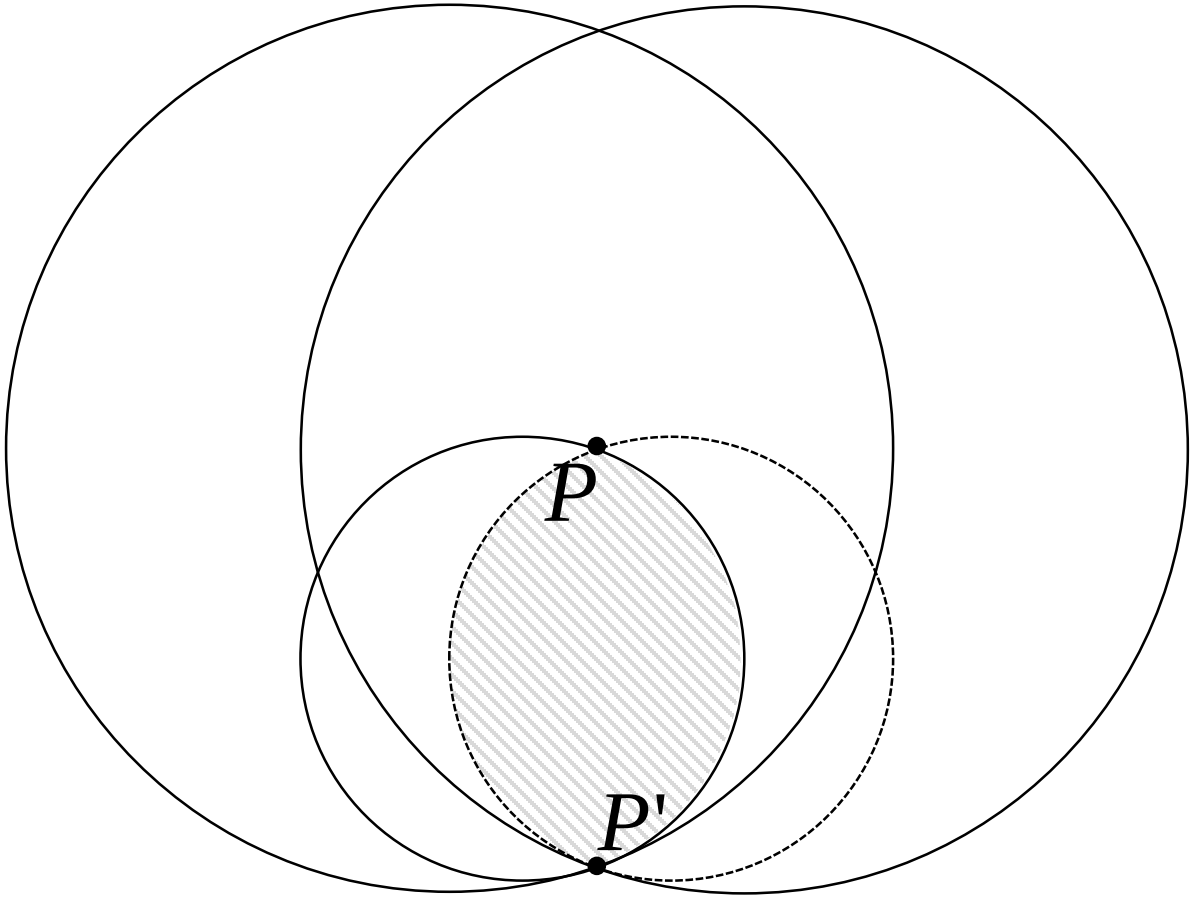
角立方逆反射可见光定位 – 设计思路

- **Derive Effective Reflecting Area (ERA)**



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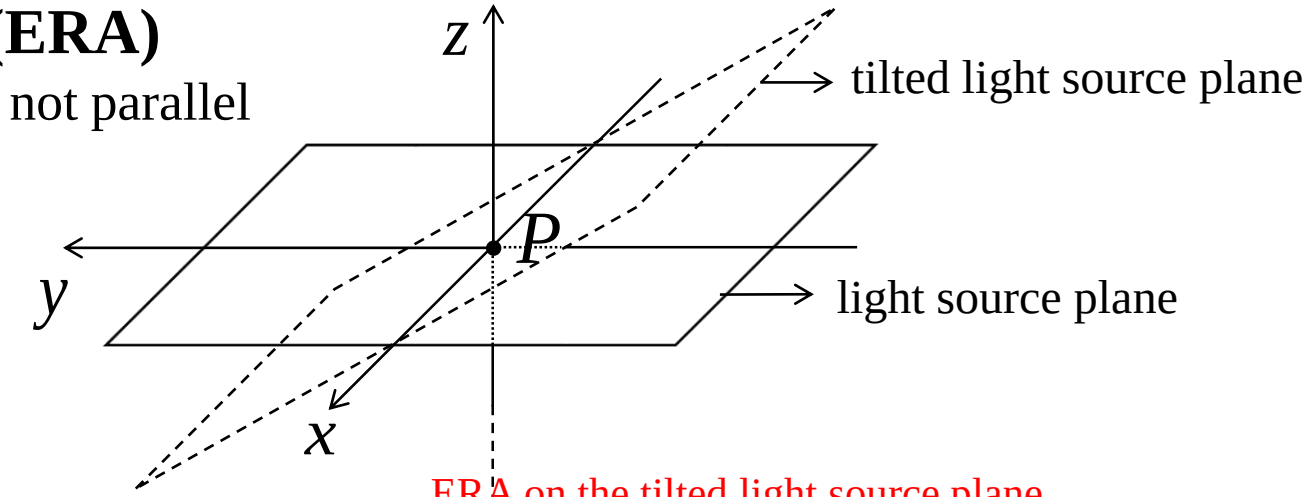
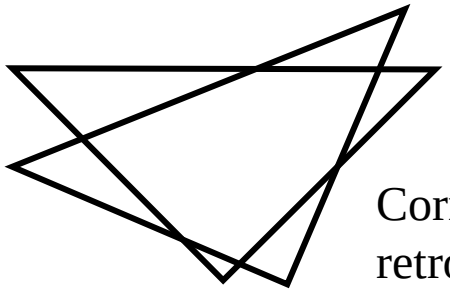
角立方逆反射可见光定位 – 设计思路

- **Derive Effective Reflecting Area (ERA)**
  - If the front face of the retroreflector is not parallel to the light source plane

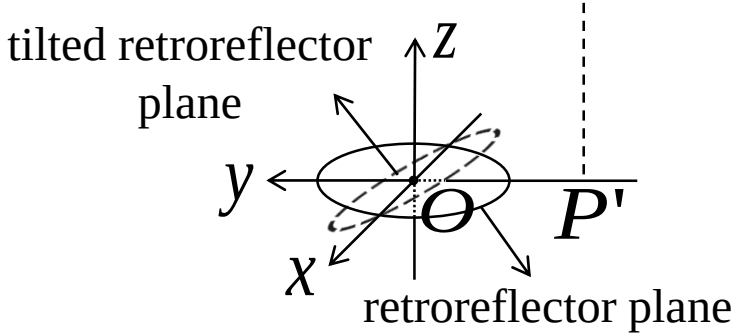


ERA on the tilted light source plane

Oblique projection to the original light source plane



Corner-cube retro-reflector



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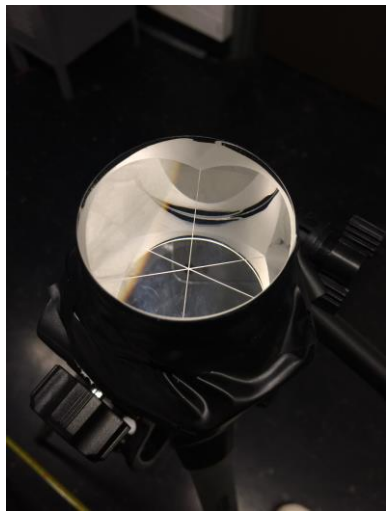
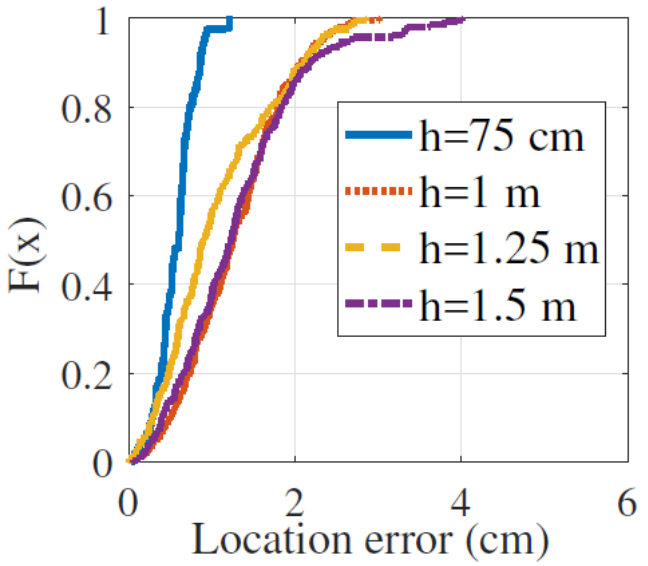
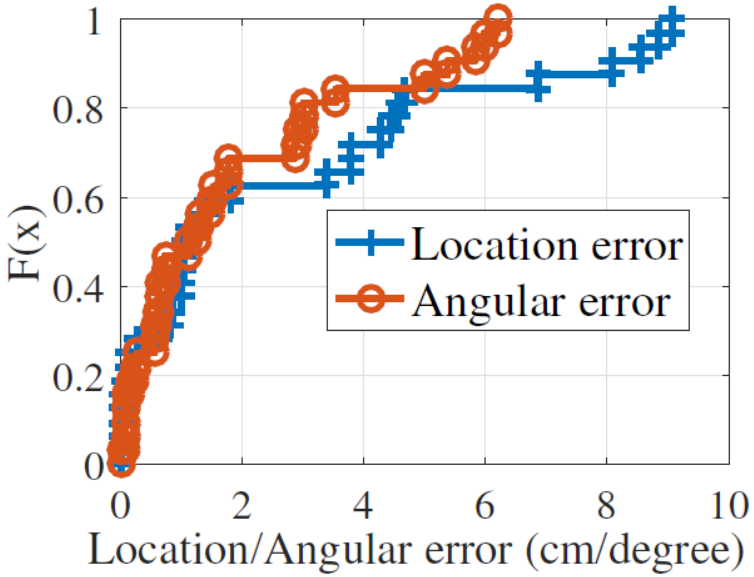
角立方逆反射可见光定位 – 实验结果



Centimeter-level location accuracy





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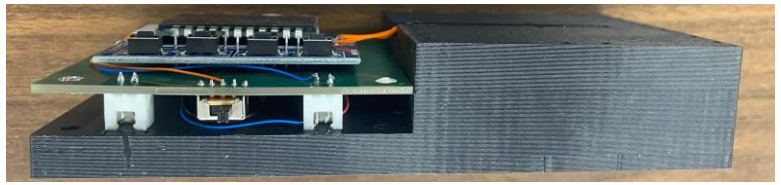
角立方逆反射可见光定位 – 样板设计

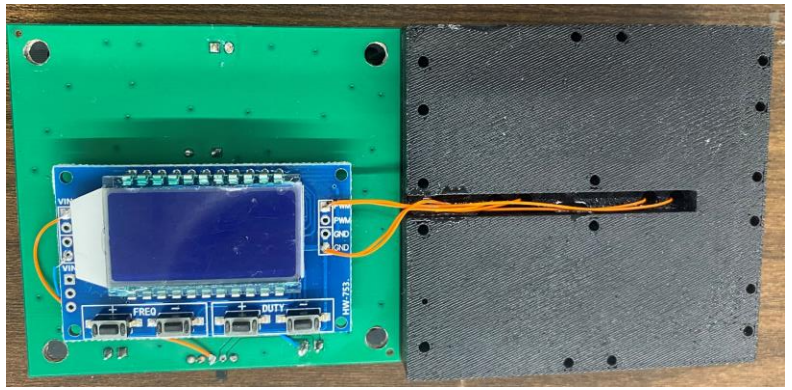
- This device is developed by my collaborator Dr. Abdallah Khreishah from New Jersey Institute of Technology.



Corner Cube Retroreflector

Solar Cell

Driver Circuit



NJIT New Jersey Institute of Technology

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逆反射可见光通信与定位 - 应用场景

- 基于无人机的智能矿井救援系统
- 仓库管理中的机器人控制
- 室内异构无线网络安全
- 基础设施到车辆的通信与定位

基于无人机的智能矿井救援系统

VLC Downlink

Reflected VLC Uplink

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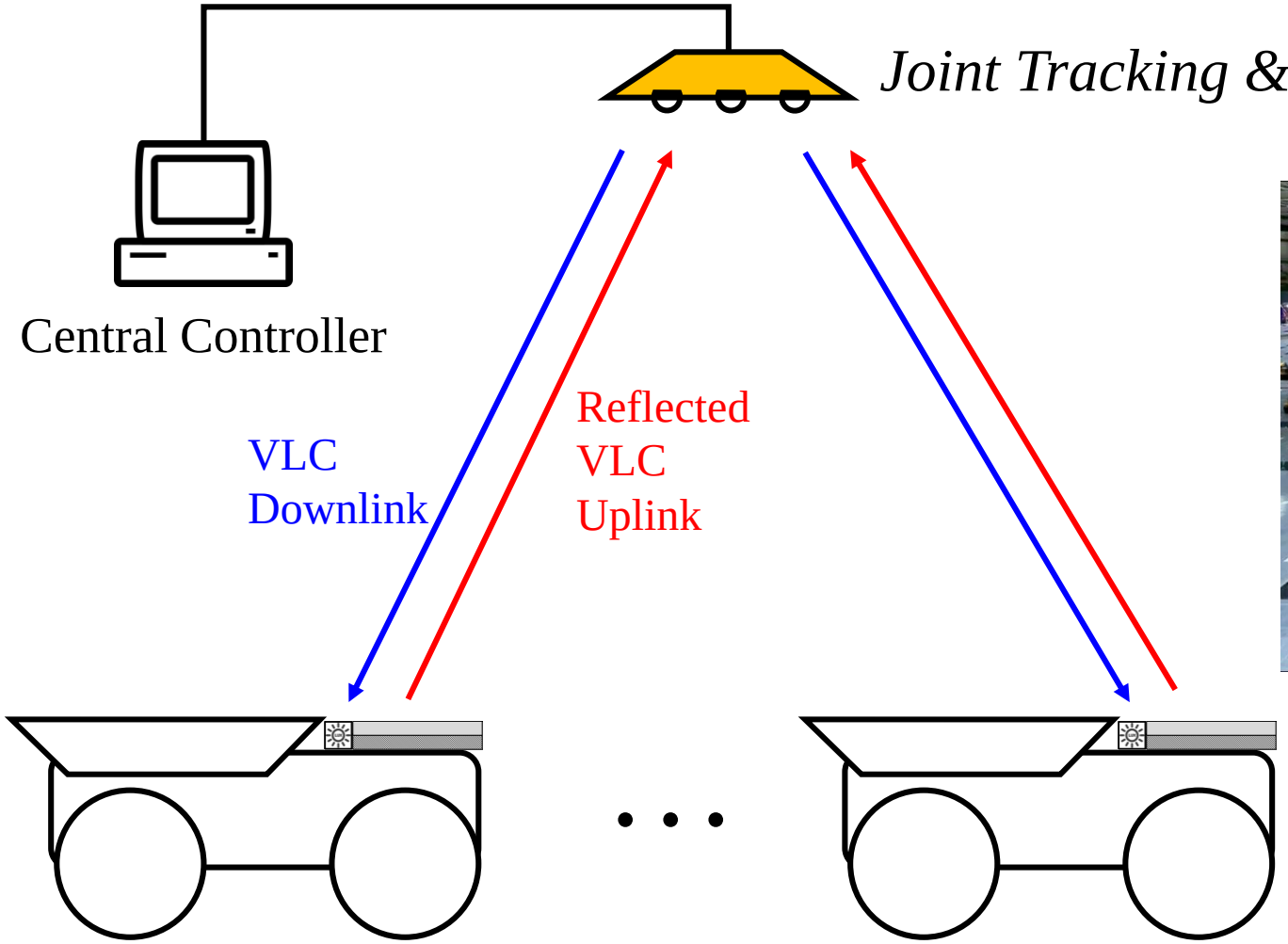
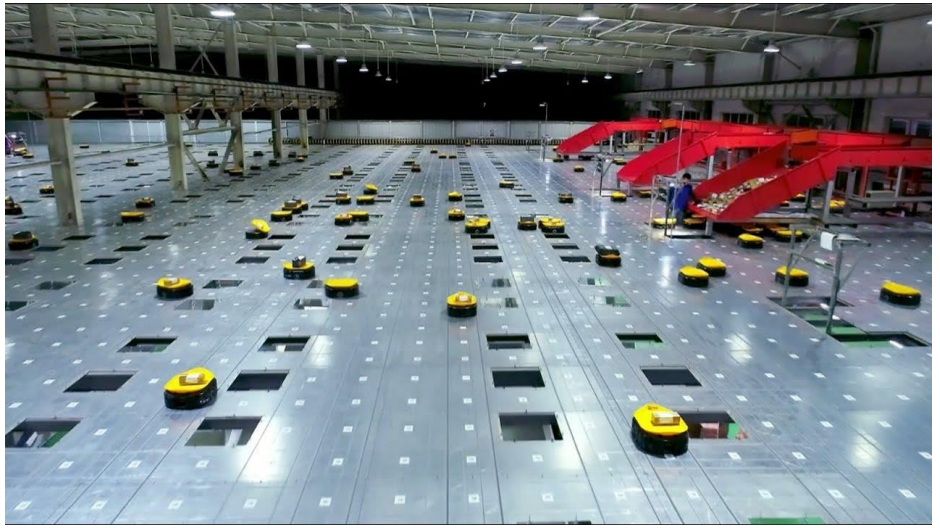
仓库管理中的机器人控制





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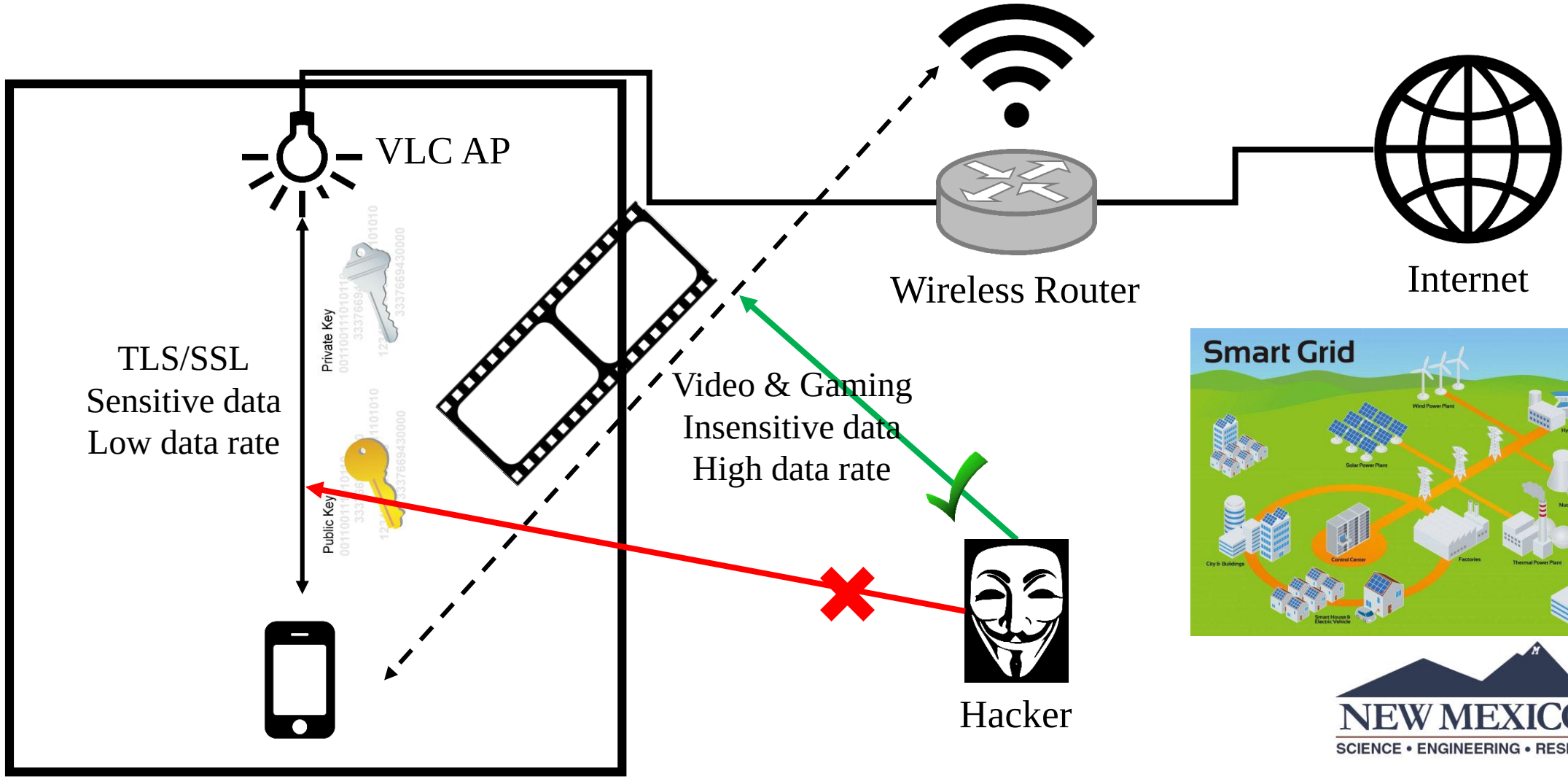
室内异构无线网络安全



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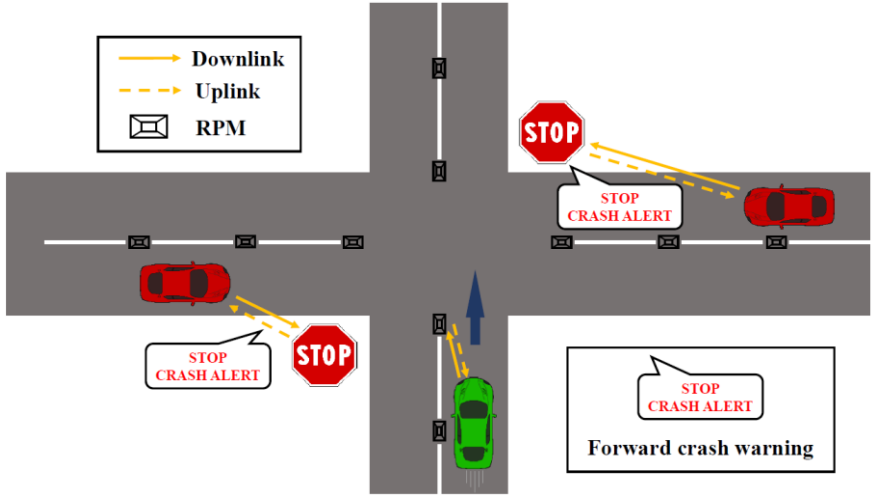
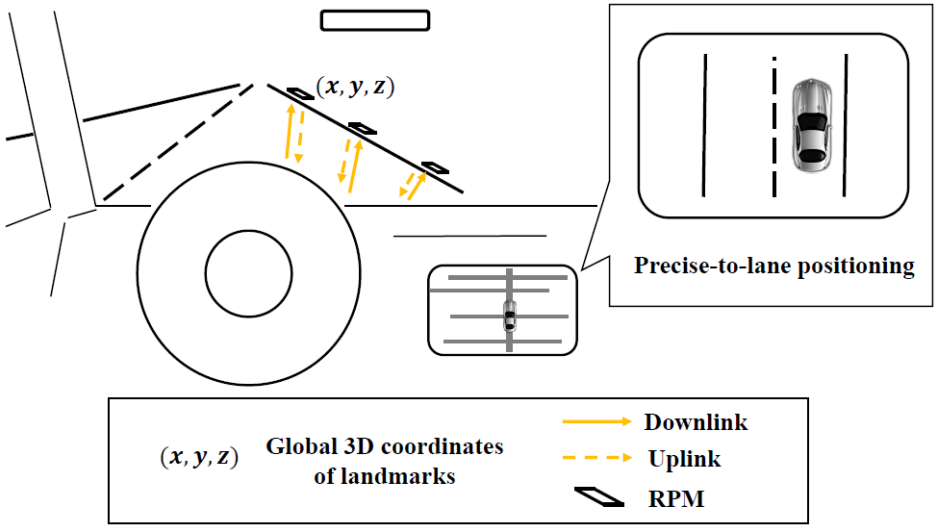
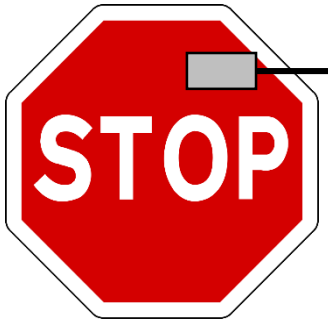
基础设施到车辆的通信与定位

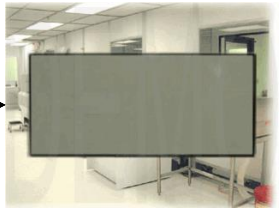
Alert



Positioning







LCD shutter

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